INTESTINAL INTUBATION

By

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My wife Lillian, whose constant encouragement and help, particularly during the early, trying days of experimentation, made this work possible

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PREFACE

The early papers of Ward, Wangensteen, Miller Abbott and Johnston created a new era in the treatment of intestinal obstruction By the use of suction applied to an indwelling gastroduodenal or intestinal decompression tube, it has been possible to reduce the mortality rate in cases of bowel obstruction from sixty per cent to less than sixteen per cent That this reduction in mortality rate was not entirely due to intestinal decompression is a universally accepted fact Our newer concept of water balance, for which we are deeply indebted to Coller and his associates, and our clearer understanding of the changes in intestinal physiology and physiological chemistry of the blood, played no small part in this reduction in mortality

Intestinal distention however is one of the important disorders of intestinal physiology as a result of an interruption of the intestinal stream from *os orum* to *os anum* For some time surgeons throughout the world felt that by the use of the Levin tube the problem of intestinal distention had been solved It was soon found that this was unfortunately not the case The introduction of the Miller Abbott and Johnston tubes in the treatment of bowel obstruction was the next logical evolutionary step in the solution of this problem Here, it was again soon found that although many cases were greatly benefited still the method of intubation required a high degree of "know how" and usually the use of fluoroscopy in these very ill patients in order to get the tubes to pass through the pylorus The literature, in the past seven years is replete with articles describing the virtues of these tubes and the great difficulty so often experienced in passing them The percentage of failures in many clinics ran as high as twenty per cent [1] We were impressed by the necessity of finding a new type of tube and a newer concept of its passage through the gastrointestinal tract We felt that in order to make the use of the

[1] Smith, B. C. Miller Abbott Tube Statistical Study of 1 000 Cases. Ann. Surg., 122 253 259 (Aug.) 1945

tube "fool-proof" it should be constructed as simply as possible and must further satisfy four criteria

The tube must have a lumen sufficiently large so that intestinal particulate matter would not plug it. In this way the care of the tube by the nursing staff could be reduced to a minimum The tube should be radio-opaque so that the roentgenologist would be in a position to know exactly where it is at all times and so that knots and kinks could be readily detected The tube should further have a sufficient number of holes so that pocketing would not occur in cases of multiple short loop obstructions The holes should be of sufficient size so that they do not become plugged readily

If such a tube could be passed far down the gastro-intestinal tract the treatment of intestinal distention would be greatly simplified Since the propulsive mechanism of all tubes resides in the head of the tube and since we found after much experimentation and thought that mercury was the best medium to be used in the head' of the tube the problem of the propulsive mechanism merely resolved itself down to placing the mercury in a very loose bag at the very tip of the tube in order to utilize all the physical properties of mercury and not merely its weight

During the early years of 1942, 1943 and 1944 many changes were made in the tube in order to make it as simple as possible A newer concept of its downward passage has been developed in this process of development

I wish to express my admiration and gratitude to Dr Daniel J Leithauser whose guidance and example has helped me to steer a straight course I should also like to express my appreciation to Dr C S Kennedy who made it possible for me to carry on this study Dr Roland P Reynolds was ever helpful particularly when the going was rough I am indebted to all the doctors on the staff of Grace Hospital for the use of their cases during the developmental stages of our simplified tube. I am particularly indebted to Dr Hans Jarre of our roentgen ray department whose suggestions were most helpful particularly in writing the chapter on the roentgenologist's role in intubation I am greatly indebted to Dr John R Paine for his very excellent summary of the history of intestinal tubes Everett R. Phelps

Ph D , and Robert H Esling M S , collaborated in studying the effect of the tension of intestinal gases upon the balloon of intestinal decompression tubes Dr Phelps, head of the department of physics at Wayne University placed the facilities of his department at our disposal to carry out this study I should like to express my appreciation to the following journals for permitting me to abstract material freely *The American Journal of Surgery Surgery, Gynecology and Obstetrics Annals of Surgery, Archives of Surgery Journal of the American Medical Association New England Medical Journal Surgery* and *American Journal of Digestive Diseases* Last, but not least I wish to thank my wife Lillian for the excellent sketches which help to clarify many points I am deeply indebted to Frank Ruslander for the excellence of his photography

I should like to express my appreciation to the firm of Charles C Thomas Publisher for many kindnesses throughout the process of compiling this material

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INTESTINAL INTUBATION

CHAPTER I

INTRODUCTION

IN THE past ten years intestinal intubation has come to occupy a very important position in the armamentarium of the surgeon in his attack upon intestinal distention. No thinking surgeon would deny the importance of decompressing the gastrointestinal tract in any case of severe distention nor can we forget that in many cases such intestinal decompression is in itself a life saving measure. Yet despite the importance of such intestinal decompression the means of securing it, namely intestinal intubation is generally intrusted to the interne who too often lacks an adequate understanding of the mechanism involved.

This past decade has seen tremendous improvements in intestinal decompression tubes as well as in methods of obtaining a negative pressure to produce suction at the end of such intestinal decompression tubes. The indications and the contra indications for the use of such tubes has gradually evolved as a result of the work of many surgeons working independently in different parts of the country. Much "water has passed under the bridge" since the early papers of Ward[2,3,4] Westerman[5] Kanavel[6] and Wangensteen and Paine[7] called the attention of the surgical world to the fact that a simple tube passed into the stomach of patients with ileus due to peritonitis would decompress these cases as well as many post-operative cases of intestinal distention. In many cases, the Levin tube passed through the pylorus and decompressed the duodenum and upper jejunum. As long as the distention was chiefly gaseous such methods of decompression were adequate. This work furnished an impetus to surgeons everywhere and succeeded in creating an "intubation era."

The early work on gastro-duodenal intubation was soon followed by an attempt to pass such tubes far down the gastrointestinal tract into the colon if need be, in order to treat intestinal distention. The demonstration by Paine[8] that negative

pressure at the end of a gastro-duodenal tube could not effectively reduce the intra luminal pressure in the ileum, and the clinical observations by surgeons everywhere that gastro-duodenal intubation was not sufficient to treat intestinal distention, resulted in a search for more effective methods When Miller Abbott combined the observations of Hotz,[9] that a balloon placed into the bowel would cause contraction of the bowel wall when the balloon was inflated, and the observations of Jones,[10] who studied intestinal pain by passing a balloon-tipped tube down the gastro-intestinal tract and noted contractions upon the inflated balloon, the result of combining both of these observations was the development of a balloon at the distal end of a double or triple lumen tube It was noted that, if the bowel in front of the balloon were decompressed and the balloon inflated peristaltic waves would be set up as a result of the inflated balloon acting like a bolus In this way, such tubes were carried down the gastro-intestinal tract in order to study the intestinal physiology and the flora at different levels of the gastro-intestinal tract.

Johnston in 1938 [11] used these long tubes in cases of bowel obstruction The need for a tube that would pass down to the point of obstruction was recognized by Johnston with the result that an attempt was made to utilize the Miller Abbott tubes for this purpose. Surgeons everywhere were quick to recognize the great value of having a tube down to the point of obstruction. The use of the Miller Abbott tube became wide spread

It was realized very shortly thereafter that there were many drawbacks to the use of the Miller Abbott tube in cases of bowel obstruction Some of these drawbacks were due to the fact that the tube itself was not the answer to the problem of intestinal distention and some of the drawbacks were due to the improper selection of cases for intubation and a lack of proper understanding of just what one could accomplish by intubation

Since 1938 much work has been done in order to more successfully treat intestinal distention and to clarify just when where and how these tubes should be used Several different types of tubes have been introduced with the objective of intubating successfully a higher percentage of cases with less effort and with tubes giving a maximum diameter of decompression Each tube

was evolved by a surgeon to meet certain physiological criteria which he thought necessary to propel the tube down the gastro-intestinal tract Classifying our tubes in use today by this standard, four different types of tubes based upon four different principles of propulsion are found in use today

The Miller Abbott tube[12] which is based upon the principle, "that it is necessary to decompress the gut in front of the balloon, so that when the balloon is inflated it acts like a bolus and is so propelled down the bowel," would then be called a double lumen "air filled bolus type tube" Successful intubation can be obtained in a good percentage of cases using this type of tube if one is willing to spend the time and use fluoroscopic control Once the patient is successfully intubated with this type of tube its downward progress is generally rapid However, being a double lumen tube with a small lumen for decompression a great deal of nursing care is required to keep the decompressing lumen open There are many modifications of this tube utilizing the same propulsive principle These tubes are double lumen with both lumina inclosed in the same sheath

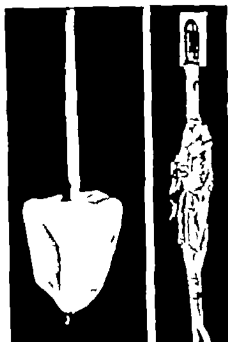


Figure 1 Figure 2

Figure 1 Tube head of Miller Abbott tube. Balloon along the shaft of the tube at its distal end. Balloon to be inflated with air Note perforated metal end projecting beyond the balloon. This is a double lumen tube inclosed in one sheath.

Figure 2. Tube head of Johnston tube. Here the double lumen tubes are not inclosed in one sheath. The small tube is used for inflation of the balloon and the large tube for decompression. Note that the balloon is attached along the shaft of the distal end of the tube and note how the tube tipped with a metal piece projects beyond the balloon. Note fenestrations in metal tip of tube

In the same classification as the Miller Abbott tube one would find the Johnston tube[13] Here we find a double lumen tube based upon the same propulsive mechanism but to avoid the

disadvantage of the small lumen used for decompression the two lumen are not in the same sheath but are made by the coaptation of two tubes side by side A small tube to inflate the balloon and a larger lumenal tube for decompression

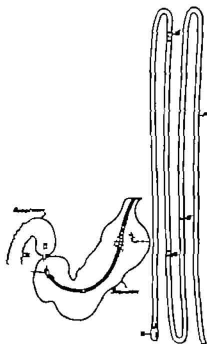


Figure 3 The Aguiar tube. This is a jet propulsion tube. The liquid or air and liquid is injected into the tube and emerges obliquely to the wall of the bowel through the metal tube head. The force of this stream propels the tube along.

The Aguiar tube[14] which was introduced in Brazil is a single lumen tube based upon the principle of jet propulsion ' The principle upon which this tube was based is the concept of the surgeon that by injecting a liquid or air or liquid and air forcibly into a single lumen tube the emission of this solution at an acute angle at the head end of the tube results in its downward propulsion This type of tube is not available in North America Most surgeons are very loath to inject any fluid or air and fluid into a gastro-intestinal tract already filled with gaseous and liquid material Although American surgeons do not use this type of tube nevertheless the development of a tube based upon the jet-propulsion' principle has been of great value in helping to crystallize our ideas as to the type of tube that would most perfectly fill the surgical requirements to induce successful intestinal intubation

As early as 1908 weighted gastro-duodenal tubes came into being with the reports of Einhorn[15] and Gross[16] working independently In the next ten years a multiplicity of gastro-duodenal tubes were developed all based upon the principle of weight of the head end of the tube as a propulsive mechanism Many metals were employed in obtaining such weighted heads Gold silver lead and mercury all had their proponents and were used in the head of a tube to weight it so that gravity would carry the

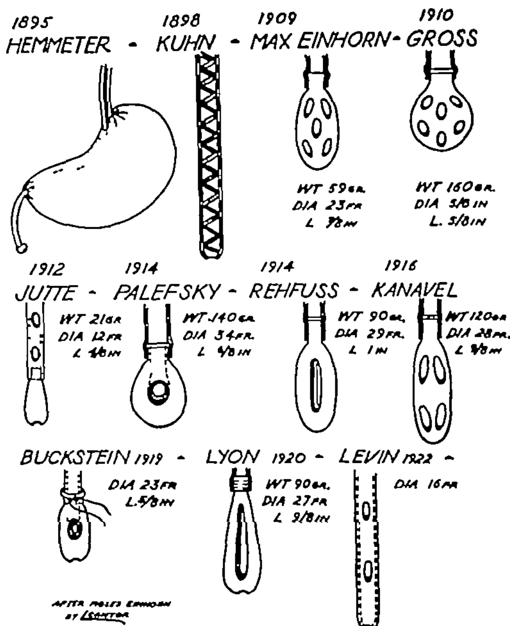


Figure 4 Note the evolutionary changes in gastro-duodenal tubes from the time of Hemmeter in 1895 Note particularly the attention given to the weight of the head and its shape. These were considered to be of the greatest importance in insuring successful duodenal intubation. (From Moses Einhorn "New Bucketless Lead Weighted Gastro-duodenal Tube with a Review of the American Contribution to the Development of These Tubes." Am J of Digest. Dis., 5 77-80 1938)

HOLLENDER 1923 - MOSES EINHORN 1926-1927

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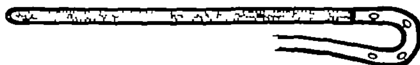
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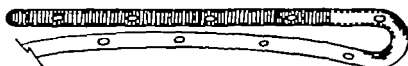
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- WILKINS 1928 -



- WANGENSTEEN 1933 -



- MOSES EINHORN 1937 -



AFTER MOSES EINHORN

Figure 4a

tube downward An outgrowth of the development of these gastro-duodenal tubes was the development of long intestinal decompression tubes also constructed upon the "weight principle. Lead in the form of an olive and attached to a tube by a suture or string has been used with some success [17] However, the many disadvantages of using an inert metal such as lead and the in ability to pass it through the nose, necessitating passage of a catheter through the nose and out through the mouth and then

pulling the proximal end of the tube through the nose after which the lead olive is swallowed, has resulted in such tubes not meeting with much favor Mercury used as weight was originally packed solidly into the head end of a three sixteenths inch tube by Wilkins[19] A modification of this is to use mercury at the head, in the balloon of a Miller Abbott, Johnston, or Harris tube[19]





Figure 5 Figure 6

Figure 5 Cantor tube. Note that the very ample loose balloon is at the tip end of the tube. This permits a "free flow" of the mercury trapped in the balloon. Note the size of the holes. This is a single lumen tube

Figure 6. Harris tube. This is a single lumen tube. Note the head of the tube Its construction is the same as that of the Miller Abbott and Johnston tubes. Notice the position of the shaft of the tube passing through the balloon containing the mercury Metal inserts at points at which balloon is tied to tube.

The fourth principle upon which the construction of a tube is based is the maximum utilization of the "free flow" of a highly mobile heavy metal such as mercury[20] To utilize this principle it should be quite obvious that none of the physical properties of mercury must be restrained For this reason, the mercury is placed in a very loose balloon at the tip end of a tube so that motion of the patient would carry it downward An attempt has been made in this type of tube to reduce the problem of intestinal intubation to its simplest possible form using a tube of the simplest possible design

The proper utilization of any of these long tubes depends more or less upon the brain of the surgeon' behind the tube A proper selection of

the tube to be used and a knowledge of the physiological principles upon which the construction of the tube is based is of the greatest value in successfully intubating any case of intestinal distention. If the interne or resident staff are to be responsible for the passage and supervision of these long tubes, then the resident staff must be adequately trained in their usage The proper use of the long intestinal decompression tube can be as important to the patient as the surgical procedure itself Often in fact, the use of a long tube is a life saving measure without surgical intervention There is no doubt that successful intubation and decompression must not be intrusted to a novice or a nurse if this surgical aid is properly to take its place in our surgical armamentarium

The field of usefulness of the long intestinal decompression tube has greatly expanded since the earliest reports of Wangensteen and Ward Successful intubation and decompression is now being practiced upon any patient with intestinal distention regardless of etiology We now know that indiscriminate use of intestinal intubation and its improper management may be fatal to the patient This is particularly true in strangulating types of bowel obstruction. Because of the great variety of intestinal disorders that can be favorably influenced by intestinal intubation we have realized the necessity for a book upon this so sadly neglected subject In this book, all phases of intestinal intubation and decompression are touched upon as well as anything that is in any way concerned with intubation or decompression. We hope to have under one cover everything that is known about this subject so that it can be readily available for quick reference

Successful intubation requires four attributes in the man who has elected to use this method of treatment First he must have common-sense This, so often neglected attribute, is of the greatest importance in the would-be intubator Without it even the simplest problems become complex Although it is true that if the patient presents merely a case of post-operative gaseous distention in whom peristaltic activity is not impaired merely dropping a long intestinal decompression tube into the stomach will usually result in successful intubation because peristaltic activity will carry it downward. Unfortunately most of the cases of intestinal distention that the surgeon is called upon to see either have very little or no peristaltic activity or the peristalsis may

be reversed In such a case intubation with the long tube requires some effort on the part of the intubator if it is to be successful By simplifying our intestinal decompression tubes, we have made it possible to avoid many of the troublesome problems incident to intubation yet common sense always must be used particularly in the unusual type of case Throughout this book we shall repeatedly call attention to this and demonstrate by concrete example how a lack of common-sense makes the use of intubation worthless. The second attribute required of the would be intubator is a knowledge of anatomy He must realize that there are many traps and pit falls through which the long tube must pass on its journey from os orum to os anum The successful avoidance of these traps depends in some measure upon one s knowledge of anatomy and the utilization of this knowledge in the proper use of the long tube The third attribute is patience and a knowledge of the physiological principle upon which the construction of the tube is based Impatience only results in coiling of the tube and a knot formation in addition to increasing the discomfort of the patient by failing to observe the niceties of intestinal intubation Rough handling of the tube or the patient will only result in cardio-spasm or pyloro-spasm because of emotional upset in the patient or as a result of a reflex from the injured nasal mucosa Gentleness and patience in passing the tube and the selection of a tube that is least likely to injure the nasal mucosa is of importance A fourth attribute is a knowledge of physiology and pharmacology A patient with chronic sinusitis and markedly engorged turbinates must be treated differently than one with a normal nasal passage We may be called upon to intubate patients with all types of nasal pathology from deviated septa or perforated septa to nasal polypi The vast majority of such cases can be successfully intubated trans-nasally utilizing our knowledge of pharmacology as to the effect of ephedrine and pontocaine upon nasal mucosa Sedation particularly in the nervous patient may make all the difference between success and failure

Once the long tube has passed into the stomach then a thorough knowledge of the physiological principle upon which the tube is based is of the greatest value in successfully passing the pylorus It should be quite apparent that an air tube would require some different maneuvering than a weighted tube or a

tube utilizing a "free flow" of mercury in a loose sac. The surgeon should know just how each tube is expected to pass downward in order to intelligently utilize it to its greatest advantage. Here again, we must call attention to the fact that patients with peristaltic activity require little or no attention as the tube will pass downward literally by itself.

A long intestinal decompression tube far down the gastro-intestinal tract solves only one phase of the problem. Improper use of negative suction pressure at the proximal end of the tube will result in no decompression. We have seen many cases in which the head of the tube was found at x-ray to be at the ileo-caecal valve, the tube patent, and yet no decompression obtained solely because there was no adequate *source of negative suction* at the proximal end of the tube. Whatever type of negative suction one chooses to employ, whether it be siphonage, bottle method of suction (Wangensteen), or some of the new mechanical pumps, some attention must be given to it to insure that it is functioning properly.



Figure 7. Note that the intestinal decompression tube (Cantor) has passed through the small intestine and the head of the tube is found in the caecum. Note the presence of the distention. An inadequate source of suction at the head end of the tube resulted in poor decompression. When a good source of negative suction pressure was applied to the proximal end of the tube decompression was prompt. Patient: C. B., White, Male, Age 58. Diagnosis: Carcinoma of the caecum.

One of the greatest advances in surgery of the gastro-intestinal tract in the past decade is the studies by Coller[21] and his co-workers upon water balance as well as more recent studies on

the chemistry of the blood These studies are particularly applicable to the after-care of the intubated patient A patient with a long tube is losing considerable amounts of water and electrolytes daily We have removed as much as five thousand cubic centimeters of liquid particulate matter in a twenty four hour period in some cases of intestinal distention In order to insure a favorable outcome to the patient a proper water and electrolyte balance must be maintained Successful intubation and decompression would be of little value if the patient would die because of altered metabolism due to dehydration or electrolyte loss A patient who is being intubated requires the surgeon to be eternally vigilant to avoid such difficulties

The studies of Leithauser upon early ambulation[22] which is being recognized as an important factor in reducing our post operative morbidity is utilized to the greatest advantage in our simplified 'free flow of mercury tube Here the motion of the patient and changes of position not only prevent post-operative vascular and pulmonary accidents but greatly aid intubation by virtue of the freely flowing mercury at the head-end of the Cantor tube which moves with each change in position of the patient Early ambulation is also of great value in preventing pulmonary complications in intubated patients Many of these patients develop an increase in bronchial and naso-pharyngeal secretions because of the presence of a tube in the naso-pharynx Such secretions dropping into the trachea and becoming inspissated could easily constitute a mucus plug resulting in atelectasis The presence of a long tube is is no way a deterrent to early ambulation. The only limitations to early ambulation are those cases described by Leithauser[22] and not a result of the presence of a long tube *per se* An occasional case of cricoid or arythenoid cartilage edema or ulceration with cord involvement[24] has been reported Such complications must be watched for by the intubating surgeon and proper measures taken to prevent injury to the patient before it occurs

The range of usefulness of the intestinal decompression tube is being extended daily with increasing benefit to the patient Simplification of the long tube and a crystallization of our ideas as to the indications and contra indications for the use of the

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Figure 7 Note that the intestinal decompression tube (Cantor) has passed through the small intestine and the head of the tube is found in the caecum. Note the presence of the distention. An inadequate source of suction at the head end of the tube resulted in poor decompression. When a good source of negative suction pressure was applied to the proximal end of the tube decompression was prompt. Patient C B White Male, Age 58. Diagnosis Carcinoma of the caecum.

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long tube has done much to insure a successful outcome. The *co-operation of surgeon and roentgenologist in many of the more* difficult cases to be intubated is essential. We have been particularly interested in evolving a practical technique of intubation so simple that it does not require fluoroscopic control and that would be adaptable for use in smaller hospitals without adequate x ray facilities as well as in smaller communities where the services of an expert roentgenologist are not available at all. We have demonstrated in well over five hundred cases that over ninety five per cent of all cases can be successfully intubated without fluoroscopic control. Check films at six and twenty four hours, although highly desirable, are not absolutely essential. An examination of the aspirated contents of the gastro-intestinal tract and the markings on the tube are quite accurate in localizing the position of the tube. We have endeavored in this work to treat the subject so that our colleagues not having metropolitan conveniences can successfully intubate and decompress such patients as require it.

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CHAPTER II

THE HISTORY OF THE INVENTION AND DEVELOPMENT OF THE GASTRO-INTESTINAL TUBES

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Supplemented by

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THE LONG intestinal decompression tube as we know it today is the result of a slow evolutionary development over a period of one hundred and eighty years. Many men contributed a little and carried the ball just a bit further In this slow evolutionary process the old axiom that necessity is the mother of invention' certainly held true, because, as the need arose for tubes and as our knowledge of the gastro-intestinal tract increased tubes were devised to meet our changing needs. From its humblest beginnings with the use of an eel skin to form a gastric tube, to our present day ten foot long radio-opaque intestinal decompression tubes, there has been a slow but steady forward progress in our attack upon the gastro-intestinal tract. At present we can with very little difficulty, pass a tube in through the nose and get it down into the sigmoid colon.

In the time of the Emperor Claudius, it was common practice at the end of a feast or banquet to serve an emetic, the vomitiom [23] with the dessert. This, when effective, gave a sense of well-being and permitted the partakers to straightway begin another feast The amount of emetic given seems to have varied considerably for often as not it produced merely an uncomfortable sense of nausea or an intractable vomiting even after

the stomach became empty Passing the finger into the posterior pharynx was another method quite commonly used by the Romans A more refined means of emptying the stomach came into favor with the use of the pinna This was a feather or group of feathers dipped in iris or cypress oil used to tickle the soft palate and posterior pharynx Indeed Agrippa is said to have had Claudius murdered by bribing his physician to use poisoned feathers

During the middle ages under different social customs the demand for agents by which the stomach could be emptied was not so great but was still present due to the popularity of poisoning as a means of murder Oribasius[26] recommended that a long leather glove finger the lower end stuffed with wool be pushed down the throat Hieronymus Mercurialis[27] advised the use of a long leather strip called lorum vomitorium ' This was coated with several unappetizing substances the basis of which was tannic acid One end of this was swallowed and the other held outside the mouth

About the middle of the seventeenth century there appeared in Europe a new and rather curious instrument which was received in Germany very enthusiastically Various names were given to it, such as magenkratzer, magenraumer magenburste [28] A rather voluminous literature extending over ninety years, sprang up concerning the indications for and the technique of its use These stomach brushes constructed of whale bone arched in almost a half circle were tipped with an ivory bead and tufts of horse hair silk, or linen Heated controversies raged at times concerning the propriety of their use In some localities they were publicly owned and kept in either the parish church or convent In other places their use was forbidden by law

We do not know definitely who first passed a tube into the human stomach or for what purpose but there are many suggestive references that it was done before the time of Physick who, by most writers is credited with the invention of the stomach tube and pump in 1800[29] It would seem probable that such intubations were not done prior to the Dutch physician and chemist Van Helmont,[30] who first made flexible catheters of leather soaked in resin in 1646 Boerhave[31] (1668 1738) another Dutch phy

sician was the first to suggest that a flexible tube be passed into *the stomach for medical purposes however, we have no record* that he ever did what he recommended

In the Philosophical Transactions (Vol 66) a paper appeared by John Hunter read March 21 1776[22] This paper entitled *Proposals for the Recovery of Persons Apparently Drowned* contains the following It will certainly prove advantageous if the same kind of steams (i e steam of volatile alkali or warm balsams and essential oils) can be conveyed into the stomach as that seat of universal sympathy will be aroused by such means. Secondly a syringe with a hollow bougie or flexible catheter of sufficient length to go into the stomach and convey stimulating matter into it without affecting the lungs

Whether anyone ever carried out these directions we do not know but in 1790 this same John Hunter[23] reported a case to the Society for Improvement of Medical and Chirurgical Knowledge as follows *A Case of Paralysis of the Muscles of Deglutition Cured by an Artificial Mode of Conveying Food and Medicines into the Stomach* We will quote the description of the instrument he used as he gave it The instrument made use of was a fresh eel skin of rather a small size, drawn over a probang and tied up at the end where it covered the sponge, and tied again close to the sponge where it fastened to the whale bone, and a small longitudinal slit was made into it just above this upper ligature To the other end of the eel skin was fixed a bladder and wooden pipe, similar to what is used in giving a clyster, only the pipe was large enough to let the end of the probang pass into the bladder without filling up the passage The probang thus covered was introduced into the stomach and the food and medicines were put into the bladder and squeezed down through the eel skin

On the basis of the above evidence, we must credit John Hunter with the first recorded use of a stomach tube In 1797 Alexander Monro III[24] delivered as his graduation dissertation at the University of Edinburgh a paper entitled *De Dysphagia* In this paper he questioned the priority of Hunter and stated that in 1767 his father had used a flexible tube of coiled wire covered with leather to remove dangerously fermenting fluids and gases from the stomachs of cattle

In his memoirs, Ambrose Pare who lived and worked in the early sixteenth century is reported to have intubated the stomach of a patient by using the stalk of a leek Baron Larrey[33] Napoleon Bonaparte's Surgeon-General, recounts in his *Memoirs* the use of stomach or esophageal tubes to feed patients with tetanus and how in the case of Marshall Murat such tubes had to be used to feed him because of a severe wound in his neck It is very doubtful however if he ever passed the tubes into the stomach for he states that the position of the tube was determined before feeding by injecting a few drops of water to see if the patient coughed

Dupuytren and Renault[34] in Paris had followed up Boerhave's suggestion that a flexible stomach tube would be a practical and useful instrument and by 1803 had perfected an instrument and published a description of it We have been unable to find evidence that they ever used the instrument except on experimental animals

EARLY APPLICATION OF STOMACH TUBES FOR THE REMOVAL OF POISONS

Philip Syng Physick a Philadelphia surgeon, knowing nothing of the preceding work began to advocate washing out the stomach with a tube and syringe in cases of poisoning in 1800 Such recommendations appeared in his lectures to the students at the University of Pennsylvania and his nephew, Dr Dorsey, had special tubes constructed for that purpose in Paris in 1803 Dorsey tried the procedure in 1809 but was unsuccessful in saving his patient The first article on the subject by Physick appeared in The Eclectic Repertory and Analytical Review (Vol 3) 1813[35] He related how on June 6 1812 he was called to visit twins, three months old who having whooping cough were each given one drop of laudanum by their mother to ensure a good night's sleep The cork had been left out of the laudanum bottle for some time and evaporation had increased the strength of the tincture so much that both babies became comatose with morphine poisoning Physick feeling certain they would die used a urethral catheter and syringe to wash out the stomachs of both infants One died, but the other completely recovered

This is the first authentic record we have of a tube being used

to remove noxious or poisonous substances from the human stomach It will be remembered that Hunter used the tube only to convey medicines and food into the stomach

On May 29, 1822, Mr Jukes,[37] an English surgeon of West minster published in an obscure periodical the Gazette of Health, a description of what he called a stomach pump ' It was made of a two-foot rubber tube one-quarter inch in diameter The distal end had several perforations and an ivory bead at the tip To the proximal end was attached an elastic bottle also made of rubber Jukes advocated the use of this instrument in cases of poisoning to empty and wash out the stomach He had experi mented on dogs and himself to prove its effectiveness In fact on one occasion he took ten ounces of laudanum into his stomach and evacuated it without harm to himself In the fall of 1822 two papers were published in the London Medical and Physical Journal One in September, was by a Mr Bush,[38] of Frome, and the other in November was by Mr Jukes

These papers described an instrument to be used for washing out the stomach in cases of poisoning Both instruments were rubbers tubes of similar make but in place of the elastic bottle used by Jukes Bush advocated the use of a syringe Jukes imme diately claimed priority on the basis of his earlier publication in the Gazette of Health Sir Astley Cooper[39] became interested in what everyone in England considered to be a new invention. At his lecture at St. Thomas Hospital Wednesday December 10 1823, he had Jukes appear and demonstrate his new instrument. The tube employed was connected with a special syringe made by Mr Reed of Kent This was considered a great improvement over the original instrument made by Jukes in 1822 because of the special construction of two valves which eliminated the neces sity of removing the syringe from the tube

With this lecture Garrison[40] says the procedure of gastric lavage in cases of poisoning became definitely established in Eng lish medical practice Thus we see that by 1823 the stomach tube had been invented in France, England and the United States and as far as can be determined, without knowledge of what had occurred in the other countries

It is hard to understand how such a useful and at times life saving procedure as gastric lavage once having come into use

could be so neglected and forgotten as seems to have been the case at the middle of the nineteenth century. The only improvement in the construction of stomach tubes or in their use from the time of Jukes' publications in 1823 to Kussmaul's classic paper in 1869 was the suggestion of Arnott in 1829[41] and Sumervail[42] in 1832 that siphonage be used in gastric lavage instead of forceful suction.

MODERN DEVELOPMENT IN THE CONSTRUCTION AND USE OF THE STOMACH TUBE

We must give credit for reviving a clinical interest in the stomach tube to Kussmaul. Through contact with Bowditch of Boston, Kussmaul was acquainted with a model of the stomach tube and pump constructed by Dr. Wyman, also of Boston. Bowditch[43] had used this to aspirate empyema cavities. He gave Kussmaul the specifications and the latter had the instrument maker, Fischer of Freiburg, make such a pump. On July 22, 1867, Kussmaul made a diagnosis of gastric dilatation due to pyloric ulcer on a peasant girl of twenty five named Marie Weiner. Using the "American pump" he treated this patient by frequently emptying and lavaging her stomach. The patient recovered. By 1869 he had treated twelve similar cases and wrote his famous paper entitled *Uber die Behandlung der Magenerweiterung durch eine neue Methode mittelst der Magenpump*.[44] This paper received a wide circulation and had a profound influence on the treatment of gastric disease throughout Europe and America. B. B. V. Lyon[45] says that this paper was directly responsible for Billroth's interest in gastric surgery. Possibilities for the diagnosis and treatment of gastric disease were seen immediately and the improvements in the instruments by which they could be made soon began to appear.

Theodore Juergensen[46] in 1870 reminded the profession again of the possible dangers of forceful suction during gastric lavage and emphasized the practicability and simplicity of siphonage. Auerback[47] and Ploss[48] independently developed double recurrent stomach tubes in 1870. Their tubes had the disadvantage of being large and causing the patient considerable discomfort when used, but gastric lavage could be done more thoroughly and more rapidly.

In 1871, Leube[49] saw clearly the diagnostic possibilities for studying gastric physiology by using the stomach tube. It was he who first suggested the test meal. In 1874, Ewald[50] and Oser[51] developed stomach tubes of soft pliable rubber and of smaller caliber than had been used previously Up to this time, stomach tubes, while flexible after a fashion, were stiff and hard and entailed in their passage a considerable unavoidable discomfort to the patient. It was considered necessary to employ a stiff tube because of the force which was used in its passage. No co-operation was expected from the patient. A few soft pliable tubes had been used but were always inserted with a stylet or mandarin. Ewald and Oser first showed that soft rubber tubes could easily be passed without stylets if the co-operation of the patient could be secured. How much this meant to the patient in the way of increased comfort can easily be imagined

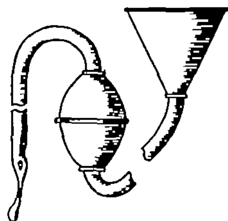


Figure 8. Gerry Stomach Pump. This was used in 1901 Olive shaped piece of rubber at end was supposed to facilitate deglutition by acting as a bolus for pharyngeal constrictors.

Our gastric tubes of today are practically the same as those used by Ewald and Oser The quality of the rubber is better but the principles of construction and the technic of insertion and use are the same. Suggested improvements have not ceased to appear but with one or two exceptions have not been accepted by the profession as practical or worthwhile Marcy,[52] in 1883, emphasized that in double recurrent tubes the efferent tube must always be larger than the afferent one This same point was later utilized by Johnston in the development of his intestinal decompression tube The last important change in the construction of the stomach tube was made by Rehfuss[53] in 1914 This tube was in fact merely a variation of Einhorn's duodenal tube used to obtain samples of duodenal and gastric contents for examination. It is not suitable for therapeutic purposes and has in no way replaced the larger caliber tubes for lavage

EARLY ATTEMPTS AT DUODENAL INTUBATION

The impetus which medical thought received from Kussmaul's paper can scarcely be over-emphasized Throughout the world investigators set about to study the physiology and pathology of the stomach, and it is not strange that experimentation soon began in an effort to make the duodenum and its secretions available for examination and analysis The duodenal tube in contrast to the stomach tube was entirely an American development and a direct result of this desire to reach the duodenum for diagnostic purposes Before the invention of the duodenal tube in America, Boas[54] and Boldyreff,[55] in Europe tried to obtain duodenal secretion Boas, by massaging the right upper quadrant of the abdomen, tried to cause a reflux of fluid through the pylorus and Boldyreff by giving fatty meals, tried to obtain the same results as an effect of normal physiology That they succeeded in some cases is undoubtedly true but neither method was practical nor reliable.

The American Fenton B Turck[56] presented to the International Medical Congress at Rome in 1894 a curious and complicated instrument which he called the "gyromele." This was a revolving flexible steel cable tipped with a spiral spring and sponge. This cable was encased in a rubber tube and at the proximal end fitted with a drill arrangement to enable it to be rapidly rotated Originally designed to outline the stomach by palpation through the abdominal wall, this instrument went through many modifications and with it Turck claimed to have intubated the duodenum and obtained duodenal secretions although few men other than himself ever used it

J C Hemmeter[57] of Baltimore, in 1896 reported certain experiments he had carried out in an attempt to intubate the duodenum He first passed a balloon into the stomach This was roughly in the shape of the stomach with a groove running along the lesser curvature Through this groove a rubber tube was passed into the duodenum To prove that the tube actually entered the duodenum Hemmeter took roentgen-rays of the tube in place But this again was an impractical and cumbersome procedure and created but little interest until brought into controversy fourteen years later after Einhorn and Gross presented their simple duodenal tubes

The German F Kuhn,[illegible] *worked with Hemmeter at Baltimore* in 1895 1896, and had assisted him with the experiments mentioned above. With a rubber covered steel spiral he tried to catheterize the pylorus directly After returning to Germany he developed the method further and wrote a description of it in 1898 In general this method was not considered reliable or practical and never received the attention which its inventor thought it deserved but it is no doubt true that Kuhn frequently was able to reach the duodenum with his spiral tube

THE INVENTION AND DEVELOPMENT OF THE MODERN DUODENAL TUBE

In 1909, almost simultaneously Maurice Gross[59] and Max Einhorn[60] presented to the medical profession a simple method of obtaining duodenal secretions Einhorn proposed a small metal olive or capsule perforated and attached to a long thin rubber tube The capsule was to be swallowed in the evening and the peristalsis of the stomach allowed to carry the tube into the duodenum The metal capsule weighed fifty nine grains and was 23 Fr in diameter Aspiration of fluid was to be done with a syringe Gross also proposed a tube which he claimed to have first introduced as a gastric tube in *1894* The tip of this tube weighed one hundred and fifty nine grains and is described as being twice the size of a pea It, too was made of metal Gross claimed that the pylorus can be reached and passed by his tube because of the adaptability of the small metal ball, which gradually leads the tube to conform to the lesser curvature of the stomach and in continuous movements glides into the antrum pyloricum His technique was to have the patient swallow the little ball smoothed with saliva until the division of forty five centimeters had reached the lips Now lightly blowing several times into the stomach would smooth it out, so that the tube would hang freely in the cavity When the patient was on his right side the tube would glide through the half opened mouth without swallowing simply following the pull of the ball until sixty centimeters was reached In another ten minutes Gross claimed that the tube was passed through the pylorus His patients were all warned not to swallow during this time in order to give

the tube an opportunity of being drawn through the pylorus by the weight of the round ball

Just as Kussmaul in 1869, had begun a new era in the study of gastric disease so Einhorn and Gross initiated another period of experimentation and study of gastro-intestinal pathology Internists were the first to fully grasp the significance of the opportunities afforded by this simple new instrument Its use quickly spread to Europe and literally dozens of men began to use it extensively The literature on the subject after 1910 is voluminous Each one who used the duodenal tube seems to have thought that he could improve on its construction or on the technic of its use As a result between forty and fifty different duodenal tubes are described in the German French and English literature The majority of them however are but variations of the original tubes and most of them employ the principle of a weighted tip and narrow soft rubber tube. The difference in the various tubes[61, 62, 63, 64, 65] as due to changes in the shape and a progressive increase in the weight of the tip of the tube from thirty three grains to one hundred and seventy grains, and the types of tip varied from the ivory ball used by Juergenson to the lead enclosed ball of Einhorn Lead gold silver bead brass, and gold plated metal all being represented in the tips of these tubes The work of Hess[66] and the tube of Levin[67] deserve special mention In 1912 the New York pediatrician Alfred Hess described the use of a small Nelaton catheter for duodenal intubation in infants Due to the anatomical relationships of the infant stomach this procedure could easily be carried out A L. Levin of New Orleans, in 1921 described his smooth catheter tipped duodenal tube for adults This tube has



Figure 9

Figure 9 Jutte Tube. Introduced in 1912 and still used for gastro-duodenal drainage. Weight of metal head 21 gr



Figure 10

Figure 10 Lyon Tube In troduced in 1920 for biliary drainage and still used today for the same purpose. Metal head weighs 90 gr

the advantage over most other duodenal tubes because it may be passed through the nares and is made of one solid piece of rubber. This tube has found increasing favor since its introduction and is used extensively for gastric lavage and aspiration.

Speed of intubation has been a goal of all who have used duodenal tubes and has been one of the reasons for the multiplicity of types developed. As noted above, Einhorn passed the tube through the mouth in the evening and allowed ten to twelve hours for peristalsis to carry it into the duodenum. Gross claimed that intubation could be done much more rapidly with his tube, using gravity as an aid to gastric peristalsis, one to two hours being the average time required. Lippman[68] made a scientific study, in 1914, of the technics used in passing duodenal tubes and developed his own technic based upon this study. His method is briefly described as follows: "The patient is placed in a chair and the freshly oiled tube passed into his fasting stomach for a distance of forty-five centimeters. After bending slightly forward for a minute, the patient partially reclines on his right side and the tube is slowly inserted twenty-five centimeters further. This position is maintained for five minutes and then the patient turns on his back and fully reclines while his hips are elevated slightly. Five minutes later the tube is inserted ten centimeters farther. This should place the tip of the duodenal tube in the duodenum. It is claimed that with this technic duodenal tubes can be passed in normal persons in fifteen to thirty minutes. Morgenstern[69] in 1931, proposed a new technic to insure the passage of these gastro-duodenal tubes through the pylorus. His technic was to push up the greater curvature of the stomach with his left hand, the patient standing in front of the fluoroscope while massaging the tube toward the pylorus with his right hand. It was claimed that by pushing upon the greater curvature that the tube head would be brought up to the same level as the pylorus and hence easily passed. Another interesting device was the so-called radiculator.[70] This was a two pronged instrument pressed against the fifth dorsal vertebral area, one prong on each side of the spine. This procedure was supposed to initiate reflex relaxation of the pyloric sphincter and permit a rapid passage of the gastro-duodenal tube.

Lake[117] in a paper entitled *The Influence of the Weight of the Duodenal Tube Tip on its Entrance Time*, reported his observations in the course of three hundred and ninety six diagnostic duodenal drainages during a three year period Four duodenal tubes were used in this study These were Rehfuss tube, Twiss tube Levin tube and Einhorn (Moses) tube The weights of their tips are Levin tube—no weighted tip Twiss tube—69 grains, Rehfuss tube—75 grains, and Einhorn tube—150 grains As a result of his observations he was able to conclude that there was no significant difference in the percentage of successes with any of these tubes in a two hour period and that the adding of a metal tip of various weights had no advantage over a plain rubber catheter With regard to whether the weighted tip caused the tube head to reach the duodenum sooner he was able to conclude that all the weighted tipped tubes regardless of their weight proceeded to the duodenum with equal rapidity and that nothing was gained by increasing the weight of the tip to 150 grains The plain catheter tipped Levin tube however appeared to proceed to the duodenum at a slower pace From his observations it would seem that a weighted tip appeared to hasten the entrance of the duodenal tube into the duodenum when compared with the speed of a plain catheter tipped Levin tube but that increasing the weight of the tip had no appreciable effect.

Many tests have been suggested and used to localize the tip of the duodenal tube All writers agree that the only positive way is by fluoroscopy or x ray The gross appearance of the aspirated contents and the reaction of the aspirated fluid however, is a fairly reliable indicator as to whether the tube has passed into the duodenum

THE CLINICAL APPLICATION OF THE DUODENAL TUBE

The more important uses to which duodenal tubes have been put will be briefly summarized with emphasis on several of these uses The examination and analysis of duodenal secretions is the prime purpose for which the duodenal tube was invented and continued to be its most important use up to about twenty four years ago During this period of time an ever widening use of

the duodenal tube as a therapeutic agent in the treatment of both medical and surgical conditions began. During the 1930's by far the greater part of the publications concerning this instrument deal with its use in the treatment of gastric and intestinal distention rather than in diagnosis. Here we find the direct forerunner of the long intestinal decompression tube being used for the same conditions which ultimately brought the long tube into being.

Gross, Schmidt[71] and Jutte[72] have all recommended duodenal lavage and duodenal insufflation of oxygen for a number of conditions, the most important being auto-intoxication and intestinal catarrh. Lyon[73] has been pre-eminently interested in the nonsurgical drainage of the gallbladder with magnesium sulphate instilled through a duodenal tube of his own design. Gantt and Weist,[74] Simon[75] and Gunn[76] have used it in the treatment of intestinal parasites. Carnot and Libert,[77] Lilienthal[78] and McDonald[79] have found it useful for feeding in cases of dysphagia, anorexia and persistent vomiting. Soper[80] recommends it in the treatment of hematemesis. Young[81] has used it for feeding in uremia. Dudko and Brailowski[82] by inflating the duodenum with air, were able to cause a nail, lodged there for two weeks, to pass. A number of writers have described its use in the treatment of peptic ulcer. The more important of these are Einhorn[83] and Buckstein.[84]

While surgeons have only of late years used the duodenal tube extensively for any purpose other than diagnosis, Westerman[85] as early as 1910 reported fifteen cases of severe peritonitis with gastro-intestinal stasis treated by continuous siphonage drainage of the stomach by means of a small tube passed through the nose but remarked that the siphonage was interrupted from time-to-time by gas. A year later Kappis[86] reported ten similar cases treated in the same way and warmly recommended that method of treatment. Kanavel[87] in 1916, recommended that closed systems be applied in the use of such tubes. Willy Meyer[88] used duodenal tubes, after gastric operations, for aspiration and administration of fluids. The general use of siphonage drainage of the stomach in post-operative treatment and in any condition accompanied by gastric and intestinal paresis was earnestly advo-

compress a markedly distended paretic gastro-intestinal tract were much more apt to be unsuccessful than in cases in which an active peristalsis was still present. For this reason and because the studies of *Miller Abbott*[94] *on intestinal physiology* and their development of a long tube which was capable of passing down into the gastro-intestinal tract to the point of obstruction, a movement toward the development of tubes that would more surely pass downward into the colon, if need be, was initiated.

THE DEVELOPMENT OF THE LONG INTESTINAL DECOMPRESSION TUBE

Intestinal intubation was successfully accomplished by Scheltema[95] in 1908 when he succeeded in passing a small tube into the bowel for the purpose of introducing medicinal substances In 1919, Einhorn used an 8 Fr tube for the same purpose but found it too small for aspiration Finally, in 1921, Einhorn,[96] still using an 8 Fr tube successfully aspirated intestinal contents for study McClendon, in 1925[97] published X rays showing that a tube could be passed into the lower ileum In 1926 Van der Reis and Shembera[98] passed a tube all through the gastro-intestinal tract and out the anus It took two to six days and repeated feedings to accomplish this so no one used the tubes for intestinal obstruction

In their original communication in 1934 Miller Abbott described[99] their technique for introducing a double lumen rubber tube tipped with an air filled balloon This tube was developed by combining the observations of Hotz that inflation of a balloon in the gastro-intestinal tract resulted in the initiation of peristaltic waves *and the studies of Jones in which a single lumen, balloon* tipped air filled tube was introduced far down the gastro-intestinal tract to study pain The original studies of Miller and Abbott and the development of their tube was, as noted, to study the intestinal flora and physiology of the gastro-intestinal tract The surgical possibilities of the long tube were not noted at that time although in a paper in 1936 by Miller Abbott, and Karr[100] they mentioned the fact that they had used their tube to study one patient with bowel obstruction due to carcinoma of the caecum In cases of obstruction they noted the aspiration of gas in front

of the balloon thus initiating peristaltic waves which carried the balloon downward like a bolus By 1938, articles appeared in the literature by Johnston[101] and his co-workers of Detroit, Klein[102] of Mt Sinai Hospital and Willson[103] of the Mayo Clinic, describing the use of the Miller Abbott tube or modifications of it in cases of bowel obstruction

The great advantages of using a long tube which would pass down to the point of obstruction were realized by surgeons everywhere and for a time it was felt that our troubles were over in the treatment of intestinal distention It was soon realized, however, that although the Miller Abbott tube was definitely a step in the right direction yet it was not the answer to the problem because of three objectionable features One of the most objectionable was the ease with which the tube became plugged by gastro-intestinal particulate matter This necessitated repeated irrigations and considerable attention by the nursing staff During the war years with the depletion of the nursing staff to the armed forces this objection was a very important one as many tubes had to be removed because of plugging of the suctioning lumen The second objectionable feature was the fact that very often the tube did not pass down into the gastro-intestinal tract. In some centers the percentage of failures was reported as being as high as twenty per cent When this occurred, the tube coiled up in the stomach and acted no better than the Levin tube despite the various technics[104, 105, 106] proposed to expedite the passage of this tube through the pylorus A third objectionable feature was the fact that there were only four small holes above the balloon and several below it and that the tube was double lumen When this tube had passed well down the gastro-intestinal tract the area of bowel about the suctioning holes would often be decompressed but secondary dilatations of the stomach might occur necessitating the use of a Levin tube in the other nostril or pocket



Figure 11 Cross sections of Miller Abbott tube (upper figure) and Cantor tube (lower figure) Note how the luminal diameter for decompression is equal to the luminal diameter for inflation of balloon in the Miller Abbott tube. Note the decompressing lumen of Cantor tube.

ing of intestinal contents proximally due to multiple short loop obstructions as a result of plastic exudate or adhesive bands. For these reasons, many modifications of the Miller Abbott tube and newer technics for using began to appear to insure the passage of the tubes through the pylorus. The Johnston tube was developed in 1938[107] in order to increase the size of the decompressing lumen. It was, however, a double lumen tube whose propulsive mechanism was an air filled balloon. In 1944 Harris[108] and *Sivertsen*[109] *suggested placing a small amount of mercury in* the balloon of a Miller Abbott tube in order to weight it. It was found that by doing so the percentage of failures decreased.

This method seemed more successful than the application of a magnetized tip as suggested by Mayer[110] who proposed to apply a magnet to the right flank and so draw the tube head through the pylorus, or the method of Abbott[105] who suggested the insertion of a stylet into the lumen of the Miller Abbott tube and under fluoroscopic control visually threading the tube through the pylorus. When it became evident that mercury alone in the balloon would carry the tube through the pylorus, a further simplification of the long intestinal decompression tube was possible. Harris[111] and Cantor[112] were both working upon the development of a single lumen tube. Harris modelled his tube head after that of the Miller Abbott and Johnston tubes, whereas, I felt that if mercury was to be used as a propulsive mechanism all the physical properties of mercury, i.e. lability, motility, and cohesive power, should be used and not merely its weight. For this reason I designed the Cantor tube specifically to carry the mercury and utilize all these physical properties. The only way this could be done was to use a single lumen tube with a loose balloon at the very tip of the tube. This would permit a free flow of the mercury which we have amply demonstrated will carry the intestinal decompression tube far down the gastro-intestinal tract even in cases of paralytic ileus. A new principle of propulsion is being emphasized, namely, the motion of the patient to carry a highly labile cohesive heavy metal trapped in a loose balloon at the tip of a tube downward into the gastro-intestinal tract.

Just as the long intestinal decompression tube underwent evolutionary changes from an eel skin to our present day single lumen

simplified intestinal decompression tube, so too, the use of mercury in intestinal obstruction also underwent changes As early as 1732, and for the next fifty years[113, 114, 115, 116, 117] numerous reports appeared in the literature discussing the use of metallic mercury by mouth in the treatment of bowel obstruction It was felt then that the metallic mercury would work its way past the obstruction and so release it This method fell into disrepute in the middle of the nineteenth century, but it called attention to the use of mercury Wilkins,[18] in 1928, utilized mercury by packing it into the end of a three sixteenths inch lumen diameter gastroduodenal tube in order to weight it for more rapid passage Then when Harris and Sievertsen in 1944, utilized mercury in the balloon of a Miller Abbott tube the true place for mercury in the treatment of bowel obstruction was obtained The natural result of combining all these observations was the inevitable construction of the simplest possible radio-opaque single lumen tube constructed specifically to carry the mercury and most effectively produce intestinal decompression

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CHAPTER III

NORMAL ANATOMY OF THE GASTRO INTESTINAL TRACT AS RELATED TO INTUBATION

THERE ARE many anatomical traps and pitfalls to halt the downward passage of the long intestinal decompression tube in its passage from os orum to os anum A knowledge by the would-be intubator of these anatomical features that must be watched for and the application of common sense readily over comes the *vast majority of these traps One must remember that* the tube passes on its course downward from the nose through the naso-pharynx, esophagus, stomach small bowel and often large bowel each of which is subject to normal as well as abnormal variations

NOSE AND NASO-PHARYNX

All of the present day long intestinal decompression tubes are intubated trans-nasally because it has been found that this route is much more comfortable for the patient It leaves the mouth *free for the ingestion of food Nature however, did not intend* the nasal passage to be used as a passageway for a foreign body such as an intestinal tube The turbinates and its covering cavernous tissue as well as the nasal septum although admirably adapted for respiration may present a real obstacle to intubation In an individual of normal body habitus, whose upper respiratory tract has not been subjected to chronic sinusitis or rhinitis or hay fever which are apt to produce a tremendous swelling of the turbinates there is usually sufficient space in the middle or inferior meatus to pass an 18 Fr intestinal tube with ease. This is particularly the case if the head end of the tube is built of a soft thin rubber balloon without any metal parts which would interfere with its

compressibility There are wide variations however, in even the normal nose with regard to the width of the passageway An individual with a broad nose will present the intubator with a wide tunnel like passage through which any size or type of intestinal tube can be passed with ease whereas an individual with a very narrow nose may present a passageway so narrow that it will require some ingenuity and the selection of the most compressible tube to pass through it Between these two extremes there are all gradations of width Johnston[118] recommends that in the narrow nose type of individual the metal end piece of his tube be removed and then re applied after the tube has passed through the nose and been fished out through the mouth after which the tube head is swallowed In some cases, it is necessary to pass a catheter through the nose and then fastening the proximal end of the double lumen tube to it, the long tube would be pulled through the naso-pharynx in a retro-grade fashion after which the tube is swallowed by the patient These maneuvers although successful are time consuming and annoying to most patients many of whom are apprehensive to begin with The result of this activity is apt to be reflex spasm of the cardiac or pyloric sphincter with a resultant inability to pass the long tube With our simplified intestinal decompression tube we believe that we have avoided this complication The balloon at the end of the tube is so soft and compressible as is the tube since there are no metal parts, that it can readily be passed atraumatically through even the narrowest of nasal passages Aside from the avoidance of discomfort to the patient, the smoothness of its passage through the nose we believe helps to prevent in great measure any reflex sphincteric spasm that is so apt to result in an unsuccessful passage of the tube

There are many deviations from the normal to be found in the nasal passage that must be watched for if intubation is to be successful Enlargement of the turbinates, whether on a congestive or inflammatory basis, may so narrow the nasal passage that no tube can be passed until proper decongestants have been applied to the nasal mucosa It is amazing how large a passage becomes available when such engorged turbinates are well shrunk

The floor of the nose may protrude upward as a variation

of the normal, making the inferior meatus unsuitable for intubation. In such cases the middle meatus can readily be used after the turbinates are shrunk.

The presence of a deviated septum will not only make intubation often impossible on the side toward which the septum is bent, but even the opposite side may present a narrowed passage due to chronic congestion and hypertrophy of the turbinates so often found in such cases. The presence of chronic infection in all such obstructive cases is the usual finding. Nasal polypi are very apt to be found concomitantly. To pass a tube through a passageway covered with an inflamed congested mucosa and to do it without pain and a minimum of discomfort requires not only some skill but a great deal of tact. It should be quite evident that a patient who is annoyed and made uncooperative because the intubator is rough and the procedure painful will not result in optimum conditions for the passage of any tube—much less a long intestinal tube.

The effect of emotions upon gastro-intestinal motility and sphincteric activity is well known.[119] Every effort must be made to pass this first barrier, the nose, as painlessly as possible and to re-assure the patient so that as close to normal intestinal conditions will prevail. When confronted by a patient with a deviated septum the only possible thing to do is to pass the tube through the side away from the deviation after adequately shrinking the nasal mucosa with ephedrine and anaesthetizing the sensitive inflamed mucosa with one or two per cent pontocaine. In the technic of inserting our simplified intestinal decompression tube three methods may be employed depending upon nasal conditions. The tip of the tube which contains the mercury may be grasped between the thumb and first finger holding it up and so forming an empty spur of balloon which is then fed into the nose with the head hyper-extended or the empty balloon may be gently pushed back into the nose by a cotton tipped applicator, or the empty balloon (portion) may be gently inserted with a bayonet forcep. In any event the head must be hyper-extended. At some time or another it will be necessary to intubate a patient with a large perforation of the nasal septum. In a case of this type methods two or three are the only possible ones to successfully

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pass a tube. Nasal polypi are not uncommonly found in the nose of patients to be intubated. Generally by shrinking the turbinates with ephedrine and a judicious application of two percent pontocaine, intubation may readily be carried out. Occasionally, the nasal passage may be found to be so filled with nasal polypi that it is impossible for the patient to breathe through the nose much less pass a tube trans-nasally. Fortunately, this state of affairs is exceedingly uncommon. In our series of over five hundred intubations we have never encountered this condition.

The naso-pharynx rarely constitutes a barrier to intubation. In children occasionally the naso-pharynx may be found to be so filled with hypertrophied adenoid tissue as to make the passage of a tube difficult. The simplified type of tube will pass however if there is any space available. These children are mouth breathers so that a diagnosis of naso-pharyngeal pathology is quite evident upon examination. Tumor masses or retro-pharyngeal infections may so narrow the naso-pharynx as to make intubation trans-orally most desirable. These complications fortunately are rather uncommon. It should be quite evident that no attempt should be made to pass a long intestinal decompression tube until a careful examination is made of the nose and throat. Much discomfort for the patient and discomfiture for the intubator may be avoided by so doing.

The oro-pharynx is rarely the seat of sufficient deviation from normal to impede intubation. Occasionally marked hyperaesthesia of the oro-pharynx particularly in a high strung nervous patient may make intubation difficult because of excessive gagging and complaints of discomfort from the foreign body (tube). Giving such patients a mild sedative and spraying pontocaine or benzocaine upon the oro-pharynx will do much to keep these people happy and comfortable during the time they are being intubated. It should be emphasized that anything that irritates the patient will be reflected by a change in intestinal motility or tone of the stomach and its sphincters. We depend upon the same action of the pharyngeal contrictors as occurs in deglutition to carry the tube through the oro-pharynx into the esophagus. Most medical centers have given up the stylet method of introducing an intestinal decompression tube. We depend solely upon the physiological

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mechanism of deglutition to pass our simplified tube so that the co-operation of the patient is essential.

After passing through the oro-pharynx and being propelled downward by the pharyngeal constrictors, the tube head appears at the esophagus at the level of the cricoid cartilage. The esophagus is a musculo-membranous tube whose function it is to carry food into the stomach. That this mechanism is a highly complex activity and depends upon an alternate contraction and relaxation of the esophagus and cardiac sphincter of the stomach is universally agreed upon. As a result, in addition to the anatomical types of obstruction to the passage of a long tube, the surgeon may encounter physiological derangements of this mechanism due either to fear, trauma, or to some abnormal physiology. In the vast majority of cases intubation through the esophagus presents no problem, the intestinal tube literally drops into the stomach. To accomplish this we do not push down upon the tube or try to forcibly pass it at any time. We depend as noted upon the action of the pharyngeal constrictors and the normal physiological mechanism of deglutition.



Figure 12. Cardiospasm due to clumsy passage of tube in a nervous patient.

A carefully taken history before intubation will readily reveal any difficulty in swallowing food or pain in the region of the esophagus. With a history of dysphagia it is well worth while to study the esophagus fluoroscopically before intubation is begun. This is particularly the case in gastric hemorrhage. Here the intubator would be very wise to make certain that the patient does not have esophageal varices that are bleeding. Intubation in such a case, particularly using any metal tipped tube, may result in a

severe esophageal hemorrhage Esophageal strictures diverticulae or obstructions of any type such as is seen in cases due to compression from without by aortic aneurysm mediastinal tumor or from neoplasia of the esophagus itself will invariably have a history of dysphagia The diagnosis of esophageal pathology by the roentgenologist prepares the surgeon for the problems to be met so that a change in intubation technic can be made to overcome the difficulty In lesions of the esophagus producing constriction so that liquid food cannot pass obviously it may be difficult or impossible to pass an intestinal tube It is quite fortunate that such pathology is rarely found in individuals to be intubated.



Figure 13 Same patient as in Fig 12 after proper sedation and passage of tube through the nose atraumatically Film taken twenty four hours after intubation.

In a general hospital such as Grace we rarely see the extreme type of cardiospasm known as achalasia The milder types of cardiospasm that we see can usually be passed by the intestinal tube Giving such patients sedatives and increasing the amount of mercury in the balloon in order to obtain its dilating effect is invariably successful

The esophagus is twenty five centimeters long from the cricoid cartilage and forty centimeters from the teeth This should be borne in mind in passing a long tube in order that too much tubing may not be passed initially In the Miller Abbott and Johnston tubes that are calibrated in centimeters sufficient amounts of tubing can be noted by the calibration. In the Cantor tube the first marking is S ' This marking is seventeen inches from the balloon thus giving ample tubing to carry the balloon into the stomach Consideration must also be given to the height of the

patient in passing this initial length of tubing A patient six feet four tall would obviously require more initial tubing than would an individual four foot ten When the extremes of size are to be intubated, the initial length of tubing must be increased or decreased in proportion

The stomach presents the greatest trap in intestinal intubation If one can successfully get the tube to pass through the stomach and pass well into the duodenum, successful intubation is generally assured The reason for the difficulty in traversing the stomach are both anatomical and physiological The anatomical reasons to be considered are, in the order of their occurrence the cardiac sphincter the posterior position of the fundus of the stomach the variability in the shape of the stomach and the pyloric sphincter



Figure 14 Position of tube head in the left para vertebral gutter with the patient flat on his back is due to the posterior position of the fundus of the stomach when patient assumes that position. Free flow of heavy metal (mercury) carries tube head to most dependent portion of stomach.

Once the tube has passed through the cardiac sphincter and drops into the stomach then the intubator is in a position to take advantage of our knowledge of the gastric anatomy in order to successfully pass through this barrier The first barrier, the cardiac sphincter having been passed we now move on to the second obstacle.

The posterior position of the fundus of the stomach with the patient on his back becomes an anatomical point of great importance when we are using intestinal tubes that are weighted This is particularly true in the use of the simplified intestinal decompression tube since the ' free flow of mercury in the balloon drags the tube into the most dependent por

tion of the stomach namely the fundus which is found in the left para vertebral gutter when the patient is flat on his back In no other portion of the gastro-intestinal tract is the position of the patient so important from the point of view of successful intubation It should be noted here that if the patient s stomach is in good tone and has normal peristaltic waves then it matters very little what position the patient assumes since the peristaltic activity will carry the tube through the stomach and into the duodenum Since most of the patients to be intubated, however present a distended stomach with either poor tone or no peristalsis or even reverse peristalsis, then it becomes exceedingly important to so maneuver the patient that our tube head, which is weighted with a labile heavy metal (mercury), can always run downhill In such cases, the tube head will run uphill with great difficulty or not at all The importance of this is quite apparent when one considers that the stomach varies widely in shape and position with changes in position of the patient and the degree of distention of the stomach In addition to these normal variations in position and form of the stomach, there are also variations in shape of the stomach in individuals of different body types Roentgenologists are wont to speak of the "J type of stomach the steer horn' type of stomach and all gradations between these two types At times the stomach may be so ptotic that the greater curvature may be found at the umbilicus or even lower whereas the pylorus and the first limb of the duodenum are fixed to the undersurface of the liver at a relatively high level When such an individual sits up a rather acute angle is formed accentuating the uphill direction of the first limb of the duodeum

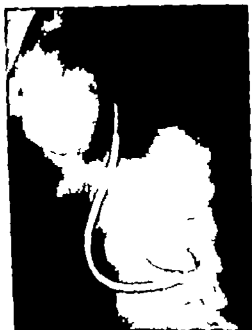


Figure 15 Note the position of the tube head when the patient assumes the erect position.



Figure 15a

The only exception to the rule that the head of the mercury weighted intestinal decompression tube will always be found in the left para vertebral gutter with the patient flat on his back occurs when the transverse colon is markedly distended When this occurs the fundus of the stomach is likely to be pushed forward so that it no longer is the most dependent portion of the stomach when the patient is on his back Under these conditions, the greater curvature would become the most dependent portion of the stomach so that the weighted tube head would be expected to be found in this area Fig 15a demonstrates this very well This patient had an obstructing carcinoma of the sigmoid colon. As a result the colon became tremendously dilated as seen in this figure. Because of this distention of the colon the fundus of the stomach was pushed forward out of the left para vertebral gutter In Fig 15a we see that with the patient flat on her back the tube head is now found at the greater curvature



Figure 16. Normal stomach upright position in an asthenic individual (a) Gas bubble at cardiac end (b) Inferior pole of stomach in this position. (c) Incisura augularis. (d) Pyloric canal markedly contracted. (e) Normal duodenal bulb (f) Second portion of duodenum. (g) Hepatic flexure of colon. (*From* Rigler L. G Outline of Roentgen Diagnosis, 2nd Ed., J B Lippincott Company Phila.)

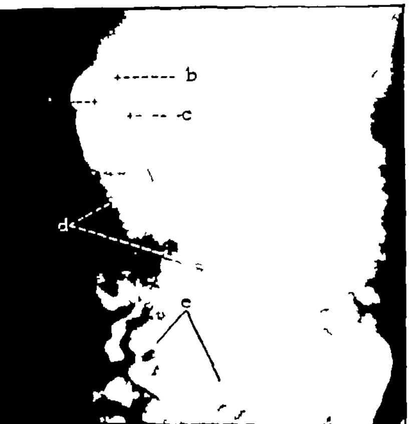


Figure 17 Normal stomach and small intestine (a) Pylorus. (b) Duodenal bulb. (c) Prepyloric notch, anatomical variation. (d) Feathery irregular distribution of barium in duodenum and jejunum. (e) More homogeneous shadow of ileum. Note difference in acuity of angle between body of stomach and pylorus between Figures 16 and 17 (*From* Rigler L. G Outline of Roentgen Diagnosis, 2nd Ed., J B Lippincott Company Phila.)



Figure 18 Stomach exhibiting normal tonus in asthenic type of individual. (*From* Buckstein J : Clinical Roentgenology of the Alimentary Tract, W B. Saunders Company Phila. 1940)



Figure 19 Stomach exhibiting hypermobility with upper displacement in the prone position (*From* Buckstein, J Clinical Roentgenology of the Alimentary Tract, W B. Saunders Company Phila., 1940)



igure 20 Displacement of the stomach to the right by a emendous distention of the splenic flexure of the colon To ccessfully intubate this stomach ambulation of the patient is sential (*From* Buckstein, J *Clinical Roentgenology of the* imentary Tract, W B. Saunders Company Phila., 1940)



Figure 21 Volvulus of the stomach with permanent displacement to the right Ambulation required for successful intubation in this type of case. Always note that patient must be put in such a position that tube head will run down hill. (*From* Buckstein J Clinical Roentgenology of the Alimentary Tract W B Saunders Company Phila., 1940)



Figure 22



Figure 23

Figure 22. Ptotic stomach with the patient in the erect position Lateral view Compare this with the position of the tube head noted in Figure 15 also taken with patient erect. Note how stomach changes in shape and position with a change in position of the patient.

Figure 23 Flat plate of the abdomen. Note how the stomach visualizes because of its gaseous content. This enables the intubator to know the type of stomach he is dealing with and plan the procedure of intubation accordingly

If our patient to be intubated has had x ray studies of his gastro-intestinal tract a brief review of the anatomy of his stomach noted on the film is of value since it tells us the type of stomach we are dealing with tely the vast majority
of patients intubated are stinal obstruction so
that barium cannot be g e, if facilities are
available, a flat plate o g the stomach
which is distended witl on to the in-
tubator A history of t some time
previously is of the grea anatomy of
that organ may have b stomach
that has had a partial g rostomy
presents a change in the neces-
sitates a change in the te

In the stomach which is atonic and *has little or no peristaltic* activity, turning the patient on his right side and slightly on his face causes the weighted tube to drop toward the apex of the stomach funnel, i e, the pylorus The first limb *of the duodenum*, however, runs uphill to a greater or lesser extent depending upon the type of stomach presented Elevation of the foot of the bed twelve to fifteen inches *results in* the first limb of the duodenum now running downhill with the result that the heavy highly mobile tube head presses against the pyloric sphincter and usually *works* through it rapidly carrying the tube down the first limb of the duodenum to the junction of the first and second limbs



Figure 24 Atonic stomach in an asthenic individual. (*From* Buckstein J Clinical Roentgenology of the Alimentary Tract W B. Saunders Co., Phila., 1940)

In the *"steer horn'* type of stomach elevation of the foot of the bed is not essential whereas in the "J' type it is imperative Since we do not as a rule know *the type of stomach we are intubating we universally employ* this position and have been highly successful in passing the tube through the pylorus The only cases in which we do not employ this position for our first maneuver to avoid the trap of the posterior position of the fundus of the stomach and the uphill curve of the first limb of the *duodenum are stomachs that have* had either partial gastric resections or gastro-enterostomies In cases of this type since the gastric stoma is now along the greater curvature it becomes the most dependent portion of the stomach with the patient erect In such cases when the tube is passed into the stomach we stand the patient up and keep them up for an hour or two in order that the tube head may drop through the gastric stoma and fall into the jejunum thus by passing the duodenum If we were to employ our usual procedure of turning the

patient on his right side and elevating the foot of the bed, it should be obvious that the tube head would pass into the proximal limb of the anastomosis and be trapped there.

Pyloro-spasm may at times prove an obstacle to successful in-



Figure 25 Normal stomach of steerhorn type in a hypersthenic individual. (a) Esophageal orifice. (b) Pylorus hidden behind stomach. (c) Duodenal bulb hidden behind antrum of stomach. (*From* Rigler L. G Outline of Roentgen Diagnosis, J B Lippincott Co., Phila.)

tubation particularly in the high strung nervous individual who has not been properly sedated and whose intubation has been roughly handled Tact on the part of the intubator and sedation of the patient will usually result in a successful passage. In a very small percentage of cases, less than five percent, despite any thing the intubator may do intubation will be impossible There are some patients who become so disturbed at the sight of an intestinal tube and the prospects of intubation that no amount of sedation will be of value An occasional patient will say I would rather be dead than have a tube stuck into me. Although such patients constitute less than one per cent of our cases, yet they are found In this group too, we would include the uncooperative patient who pulls the tube out during the night despite our efforts to keep it in

Pyloric stenosis, a not unusual finding may present a real obstacle to successful intubation and one that may be unsur

mountable Leithauser[170] has reported a case of this type in which solid food would not pass through the pylorus, but a simplified intestinal tube did pass through permitting trans tubal feeding.





Figure 26 Figure 27

Figure 26. Stomach following partial gastrectomy of Polya type. Food would not go through the stoma. All food ingested was vomited. Cantor tube successfully passed by increasing the amount of mercury used in balloon. Alimentation via tube in small bowel. (Courtesy of D J Leithauser M.D)

Figure 27 When the marking "D" of the Cantor tube appears at the nose note the position of the tube head just beyond the duodeno-jejunal flexure

In cases of this type, an increase in the amount of mercury used in the balloon to seven or eight cubic centimeters will often result in successful intubation

The tone of the stomach is of great importance in intubation If the stomach is in a state of good tone any tube will rapidly pass through In an atonic stomach or one having reverse peristalsis, attention to the details of intubation to avoid the traps and pitfalls found in this organ will insure a successful intubation in well over ninety five percent of all cases The calibration of

the simplified intestinal tube is such that twelve inches is allowed to carry the tube head well down the duodenum through the stomach before the marking "D" appears at the nose. In using the Miller Abbott or Johnston tubes that are calibrated in centimeters the tube is introduced to the sixty centimeter mark without suction and then the tube is advanced one inch every ten minutes until the seventy five centimeter mark is reached This should bring the tube through the stomach and well along the doudenum

The first limb of the duodenum runs upward and backward whereas the second limb runs downward and the third limb passes from right to left and slightly upward In intubation with the Miller Abbott or Johnston tubes, which depend upon the downward propulsion of the tube by an air filled balloon no special postural management is required although all patients are turned on the right side With the simplified intestinal decompression tube (Cantor) maneuvering the patient so that the highly mobile head can always run downhill necessitates utilizing our knowledge of the anatomy of the duodenum Since the first limb of the duodenum runs upward and backward we turn the patient on his right side toward his face and elevate the foot of the bed This maneuver brings the first limb of the duodenum downhill The second limb of the duodenum passing downhill we must reverse this Trendelenberg position after the tube has passed through the first limb of the duodenum The presence of bile in the fluid aspirated verifies that the

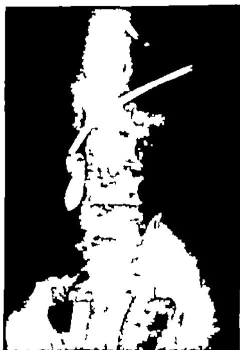


Figure 28 When the marking "P" appears at the nose the tube head is usually in the second portion of the duodenum as noted here. Note how the *tube head appears to pull the tube down.*

tube is in the duodenum A Fowler s position brings the second limb of the duodenum downhill so that again the mobile head of the tube can pass downhill The third limb of the duodenum passes from right to left and slightly upward To utilize this anatomical fact we turn the patient on his left side creating a downhill course for the mobile weighted tube head By turning and moving the patient we are able to constantly cause the tube to run down hill in its course through the duodenum In cases of bowel atony or reverse peristalsis these maneuvers are important for proper intubation as we do not depend upon peristaltic activity to carry the tube onward here but merely a free flow of a highly mobile cohesive heavy metal trapped in a loose balloon at the end of a tube It will always run downhill under these conditions but not uphill



Figure 29 Note how the tube head drags the Cantor tube through the stomach down the second portion of the duodenum, across the third limb of the duodenum and into the duodeno-jejunal flexure

The ligament of Treitz has not received the attention that it deserves as a barrier to intestinal intubation Surgeons generally are only interested in whether the intestinal tube head has passed through the pylorus From then on the tube is supposed to pass down the gastro-intestional tract without any difficulty Once the tube head is shown by radiography to be in the duodenum then the intubation is considered as being successful Unfortunately in many cases the tube head passes through the pylorus only to become arrested at the distal end of the third part of the duodenum It may remain at this site for days with the result that complete intestinal decompression is not obtained

In studying this problem two important factors were found

to be responsible for this barrier to an otherwise successful intestinal intubation. On the one hand, the length of the Ligament of Treitz, and on the other hand the weight of the fluid and gas filled loop of jejunum into which the duodenum empties. It should be quite obvious that an intestinal decompression tube whose downward course is arrested at the duodeno-jejunal flexure is not as effective a decompression unit as the tube would be in the ileum. For this reason, the importance of any barrier to an other wise successful intubation must not be minimized.

Anatomists describe the Ligament of Treitz as the suspensory muscle of the duodenum. It is a bundle of involuntary muscle fibers running from the left pillar of the diaphragm to the duodeno-jejunal angle.[121] Cunningham[121b] describes the Ligament of Treitz as a muscular band that springs from the right crus of the diaphragm on both sides of the esophageal opening. It then descends over the left crus behind the coeliac plexus, the splenic and left renal veins, and the pancreas and then inserts into the duodeno-jejunal flexure. In children this muscle is well marked and easily isolated and some of its fibers can be traced into the root of the mesentery where they are inserted into the peritoneum. *In the adult it becomes ligamentous and loose and is difficult to* distinguish from the surrounding fibrous tissue.

The function of the Ligament of Treitz is to prevent the duodeno-jejunal flexure from being dragged downward by the weight of the jejunum. It tends to keep the fourth part of the duodenum relatively at a fixed point.

Anatomists have described the variation in the curve of the duodenum as a result of the variation in the position of the third portion of the duodenum. The third portion of the duodenum is described as being either nearly horizontal and the fourth part nearly vertical or the third portion of the duodenum may incline upwards as it passes to the left and then it would lie in line with the fourth portion of the duodenum.

An examination of thirty five cadavers by the author has demonstrated that there is a considerable variation in the obliquity with which the third portion of the duodenum passes from right to left and associated with this there is a concomitant variation in the length of the Ligament of Treitz. Just as the position and

type of the stomach seems to be associated with the body build or habitus of the individual, so also does the angulation of the third and fourth portions of the duodenum appear to vary with the length of the Ligament of Treitz In individuals with a short Ligament of Treitz the third portion of the duodenum was invariably found to angulate upward at a fairly acute angle in its passage from right to left The shortness of the Ligament of Treitz in this type of individual would result in a rather marked angulation at the duodeno-jejunal flexure On the other hand individuals with a long Ligament of Treitz presented a third portion of the duodenum almost horizontal and with a far less acute angle at the duodeno-jejunal flexure In some cases the direction of the third portion of the duodenum was such that almost no angle was found between the fourth part of the duodenum and the jejunum

In measuring the Ligament of Treitz in the thirty five cadavers we found the shortest ligament to be one half inch long and the longest two and one half inches long The measurements were made from the upper surface of the duodenum to the point of attachment of the ligament to the vertebral column Nine of the cadavers (26%) were found to have a Ligament of Treitz that measured one half inch in length Every one of these cadavers presented a third portion of the duodenum with a very acute angle upward and to the left and with a very acute angle at the duodeno-jejunal flexure This acute angle could constitute a barrier to intubation In Fig 29a note the very acute angle at which the third portion of the duodenum passes upward and to the left and note the acuity of the angle at the duodeno-jejunal flexure In four of the cadavers (11%) the Ligament of Treitz was found to be two and one half inches long Associated with this long ligament the third portion of the duodenum passed almost horizontally from right to left and the duodeno-jejunal flexure was obtuse In Fig 29b note that the duodenum is almost horizontal across the abdomen Such cases would be easily intubated Twenty two of the cadavers (62%) presented a third portion of the duodenum occupying an intermediary position to that noted in Figs 29a and 29b In these twenty-two cadavers the Ligament of Treitz ranged from three-quarters of an inch to

one and one-half inches in length Fig 29c is an example of this type of duodenum with a Ligament of Treitz of average length

The clinical application of these anatomical observations can be directly noted in intubating the duodenum In studying a large *number of patients we have been able to divide them into three groups with regard to the ease of intubating the duodenum*

In our first group we find a well marked angulation upward of the third portion of the duodenum A study of Fig 29e discloses a well marked angulation upward as the tube passes through the third portion of the duodenum Note the obliquity of the tube as it passes through this portion of the bowel and the tendency to kink at the junction of the second and third portions of the duodenum. *Note that the weighted mercury head has* dropped into the jejunum This tube was arrested at this point for two days It was necessary to ambulate this patient before the tube head advanced beyond this point By ambulation we permitted the maximum utilization of the downward pull of the tube and. In cases of this type ambulation must often be resorted to intubation beyond this point is desired. This is particularly the case in patients with atonic or paralytic ileus

In our second group we find a horizontal third portion of ... duodenum and almost no angle at the duodeno-jejunal flexure ... demonstrates an intestinal tube horizontally in the third ... the duodenum Note how the tube head dips down... Cases of this type are very easy to intubate and rarely ... the downward passage of the intestinal decompression

duod... third group we have the third portion of the duo... portion... an intermediary position between the acuity of describe... noted in groups one and two Note in Fig 29f the nearly ver... tube passes through the third portion of the duo... upwards ... ad projects well into the jejunum Note the ... e third portion of the duodenum pro... is not nearly as acute as in figure ... lly easy to intubate although which ... insure further progress of lett ... the l ... of intestinal distention, in



Figure 29a



Figure 29b

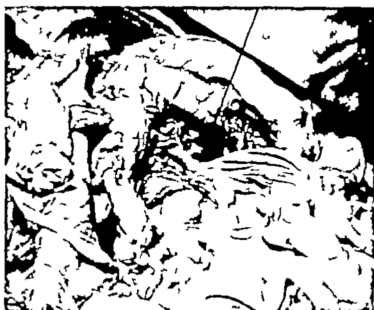


Figure 29c



Figure 29d



Figure 29e

which the distending elements are fluid and gas the jejunum is filled and weighted it becomes obvious that the downward drag of this weighted jejunum would markedly increase the obliquity of the duodeno-jejunal flexure In many cases of paralytic ileus the distended jejunum becomes so heavy as to almost entirely close off the end of the duodenum in those patients whose duodenal angle falls in group one In such cases the shortness of the Ligament of Treitz constitutes a considerable barrier to intubation and one to be reckoned with



Figure 29f

After the tube has reached the duodeno-jejunal flexure the anatomy of the small bowel requires other procedures It has been well demonstrated by Miller Abbott and Johnston that the balloon acts like a bolus to initiate peristaltic waves and carry their tubes downward through the small bowel This same mechanism also occurs with the Harris and Cantor tubes A loose balloon at the end of a tube, as found in the simplified intestinal decompression tube, constitutes a sufficient bolus as tubes A loose balloon at the end of a tube, as found in the simplified intestinal decompression tube constitutes a sufficient bolus as to be carried downward by peristalsis, if there is any On the other hand in an atonic bowel motion of the patient and frequent changes in position results in motion of the mobile mercury in the tube head which easily carries the simplified tube down the loops of small bowel Many changes of position and motion of the patient are highly desirable because of the different planes that the loops of distended bowel lie in If there is no contraindication to ambulation this will greatly facilitate the downward

passage of the tube Decompression is prompt due to the large lumenal diameter so that peristaltic waves are soon set up

It must be remembered that the small intestine is essentially a non-rigid mobile tube lying in every conceivable plane, but suspended by six inches of mesentery which is attached across the posterior area of the abdomen obliquely from left to right and downward It has been amply demonstrated by Paine [121] and by many clinical observers that where the small bowel is filled with swallowed air as in post operative distention, any tube in the stomach or upper duodenum will decompress the jejunum because of the tendency on the part of gases to equalize their pressures and the elasticity of the bowel wall pushing upon the intra luminally trapped air When the *small bowel is filled with air* and fluid, however such as is seen in severe post-operative distention or bowel obstruction which is advanced then, the laws of diffusion of gases no longer hold since we have a mixture of *gas and fluid Furthermore the multiplicity of planes* that the loops of bowel lie in create in reality a multiple short loop obstruction phenomenon This can only occur in a structure such as the small intestine because of its peculiar anatomy It should be quite evident that a long intestinal decompression tube passed well down into the small bowel would not only decompress the bowel but also prevent pocketing since the entire twenty four feet of small bowel is often strung along four feet of tubing The effect is in reality a pleating of small bowel along the tube and not intussusception-like infolding In its downward course through this small bowel that has been discussed if one uses a simplified



Figure 30 Obstruction by an adhesive band at the hepatic flexure of the colon. Note the position of tube head in the caecum.

intestinal decompression tube (Cantor) with a free flowing mercury in its head many changes of position of the patient ambulation wherever possible and motion in different planes will usually effectively result in small bowel intubation



Figure 31



Figure 32

Figure 31 Note position of tube head in the ascending colon. Patient A. L., White female Age 60 Diagnosis Carcinoma of sigmoid colon.

Figure 32. Note the position of the tube head in the sigmoid colon.

For purposes of intubation the colon is divided into right and left halves with the mid-point of the transverse colon marking the dividing line The colon does not require any special maneuvre to be intubated Generally when the intestinal tube has reached the ileo-caecal valve the small bowel peristalsis has been restored sufficiently as to pass the tube into the colon and usually along it The remarks relative to the tube running uphill that were applicable to intubation of the first limb of the duodenum do not apply in this viscus for the reason that we now have peristaltic activity while in the stomach we had either atony or reverse peristalsis Even in obstructions of the sigmoid colon it is often possible

to intubate the colon The *division into right half and lef* of the colon for purposes of intubation is due to the fact t dealing with obstructive lesions of the right half of the intestinal intubation to or through the ileo-caecal valve wil fectly decompress the bowel proximal to the point of obstruction making possible a one stage resection and anastomosis without preliminary or concomitant enterostomy In this way, a so-called "non surgical enterostomy" is made *available for the surgeon giv*ing him time to adequately prepare his patient for surgery The surgical procedure is greatly simplified by virtue of the peculiar anatomy of the small bowel that permits it to be *strung along four feet of* tubing and so well out of the operative field.



Figure 33 Cantor tube has *through the gastro-intestinal tra* emerged from the anus. This oc twenty four hours after success fu bation. Tube was removed from Patient M K., White Female, A Diagnosis Ileo transverse colo after resection of the right colo *testinal distention post-operat*

The left colon does not lend itself as well to intubation *as the right colon. At times* the intestinal tube will not pass through the ileo-caecal valve so that the colon proximal to the sigmoid may not be decompressible Although the right may be filled with gas and liquid *particulate material whi* capable of being aspirated through an 18 Fr intestinal tube often the left colon whose chief function is storage, is filled firm or inspissated feces that cannot conceivably be aspi through a tube A defunctionizing transverse colostomy i excellent procedure in such cases *However there are indica* for colonic intubation even in left sided colon lesions which be discussed in a later chapter

In the removal of intestinal tubes that have passed into the colon, thirty minutes or more should be allowed A firm but gentle traction upon the tube will readily remove it Remember that there is pleating of twenty four feet of small bowel along four feet of tubing—gentleness is the answer to painless extraction Occasionally a spasm at the ileo-caecal valve duodeno-jejunal flexure pylorus or cardia of the stomach may arrest the extraction of the tube Giving the patient a sedative, not morphine and leaving him alone for thirty minutes or longer will invariably result in a release of the spasm and an effortless extraction of the tube Where the tube has emerged from the anus however, it is esthetically more desirable to pull the tube out from below

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CHAPTER II

INTESTINAL PHYSIOLOGY AS RELATED TO INTESTINAL INTUBATION

SUCCESSFUL intestinal intubation requires a knowledge the normal as well as the changes in intestinal physiol as a result of disease. Since our tubes are intestinal decompress tubes their greatest field of usefulness occurs in cases of intesti distention regardless of etiology Intestinal distention implies paired intestinal motility and often a reversal of the normal di tion of peristalsis In addition, sphincteric spasm often constitu an almost insurmountable barrier to successful intubation. T character of the intestinal content in the different divisions of gastro-intestinal tract and the secretory activity of portions of bowel constitute an important consideration in intubation

In the naso-pharynx and oro-pharynx the mucosa is norma moist and sensitive. The presence of a foreign body such as intestinal tube for any length of time results in an irritation a congestion of the pharyngeal mucosa This manifests itself a feeling of dryness in the throat or by an increase in secreti of the nasal and bronchial glands This is particularly apt occur in smokers who have increased post-nasal drainage ev prior to intubation The increase in secretory activity of the glan may be complicated by some dehydration which can then resu in the formation of thick mucous plugs The danger of atelecta from this source is real and must be guarded against by drinki fluids keeping the tube moist with fine oil and motion of t patient as well as ambulation whenever possible to prevent su complications Chondritis and ulceration of the vocal cords ha been reported as a result of intubation The cases[182] report followed the use of double lumen tubes It is possible that th were the result of the initial trauma by the metal heads on th tubes since we have not as yet had this complication appear must be watched for

We depend upon the physiological activities of the pharyngeal constrictors for successful intubation The mechanism of swallowing food in which the pharyngeal constrictors contract behind the bolus of food and propel it downward is also ultilized in intubation We give the patient water to drink while passing the tube With each act of swallowing, the tube is gently passed downward with the bolus of liquid We discourage forcibly pushing the tube downward against the pharyngeal constrictors, but stress the fact that the tubes must be carried downward into the stomach as physiologically as food In the vast majority of cases to be intubated, the patient although vomiting as a result of reversal of the intestinal stream will nevertheless have a normal swallowing reflex so that normal deglutition is possible

There are unusual cases in which the swallowing reflex is impaired so that the intubator must resort to a change in technic to get the tube into the stomach Lesions of the vagus nerve or the recurrent laryngeal nerve are prone to produce a difficulty in swallowing The so-called achalasia of the esophagus[123] results in a spasm at the cardiac sphincter making successful intubation difficult. In such cases, there is always a history of difficulty in swallowing In this way, a diagnosis of the lesion present could be made before intubation is attempted If the disturbance in deglutition is due to a derangement in physiology, as noted, then increasing the amount of mercury to seven or eight cubic centimeters and standing the patient up will invariably result in a successfully passed tube into the stomach The motility of the mercury in the loose sac and the effect of gravity would literally shoot the tube into the stomach Where the cardiac sphincter is spastic, ambulation with the weighted loose balloon in place often creates the same effect as the dilatation of the cervix uteri by a dilating projection of membranes of pregnancy The free flowing mercury tries to find the most dependent level and its cohesive power tends to draw the rest of the mercury and tube head after it Fortunately these extreme degrees of cardio-spasm are uncommon The milder forms of cardio-spasm are reflex in origin due to fear emotional instability or trauma to the nasal mucosa by a rough intubation. Adequate sedation for the patient and gentleness on the part of the intubator will avoid most of these cases



Figure 34 Hypotonic stomach in a hyposthenic individual. (*From* Buckstein, J Clinical Roentgenology of the Alimentary Tract W B Saunders Co. Phila., 1946)

The tonus of the stomach and the condition of the pyloric sphincter are important for successful intubation An atonic stomach with a spastic pylorus creates a difficult situation for the intubator Most of the stomachs that are to be intubated are distended. Where the stomach is in tonus and normal peristaltic



Figure 35 Transverse hypertonic type of stomach in a hypersthenic individual. Ambulation required for successful intubation in this type of patient. Sedation imperative before beginning to intubate. (*From* Buckstein, J Clinical Roentgenology of the Alimentary Tract, W B Saunders Co., Phila., 1940)

waves are present as in cases in which intubation is resorted to preliminary to resection of the right colon, no special maneuvers are required In such cases, the intestinal tube will be rapidly passed onward with the ingested food. However since the vast majority of cases to be intubated present some alteration in gastric motility or tonus, this must be taken into consideration

If an intestinal decompression tube is to be passed post-operative, it is essential to remember that in the first six hours post operative that there is atony of the stomach For this reason if such a stomach is intubated immediately post-operative and so kept empty of gas and fluid it is far better to leave it in situ for six hours before maneuvering the patient in an attempt to pass the tube through the pylorus By waiting the stomach will be permitted to regain its tonus and motility with the result that intubation will be greatly simplified Any attempt to pass the long tube through the pylorus immediately post-operative may be unsuccessful

at intervals and the antral contractions forces some of the liquified food through The pyloric ring relaxes at irregular intervals and not with each gastric contraction wave It has been shown by Cannon[127] that solid objects forced against the pylorus prevent relaxation of the sphincter and retard the passage of gastric chyme Liquid food may be forced into the duodenum within a few minutes There is in addition a specific food reaction Carbohydrate foods begin to pass out of the stomach soon after ingestion and requires only about one half as much time as the proteins Fats remain in the stomach for the longest time when taken alone Hydrochloric acid in the stomach seems to favor or produce a relaxation of the pyloric sphincter according to Cannon although it causes a contraction of the duodenum Johnston[128] and co-workers have shown again that there is a specific emptying time for each type of food ingested Cannon's observations indicated as did those of Grützner, that material may remain in the fundic portion of the stomach for a long time until the tonus of the stomach forces it out of the fundus toward the antrum

The importance of these physiological observations cannot be minimized in intestinal intubation because in difficult cases every scrap of knowledge of the normal physiology of the stomach must be utilized if intubation is to be successful. As noted above, the chief function of the fundus of the stomach is storage We have shown that anatomically the fundus of the stomach comes to lie in the left para vertebral gutter when the patient lies flat on his back. Under normal conditions the tonus of the stomach will push the tube from the fundus to the antrum and then through the pylorus regardless of the position the patient assumed The patient with intestinal distention is usually one who has an atonic stomach or one with reverse peristalsis As a result of the loss of stomach tone, when the patient lies on his back the tube head comes to lie in the fundus of the stomach in the left para vertebral gutter and remains there because that is the most dependant portion of the stomach The only way that the tube head can be moved out of that situation is to maneuver the patient so that the pylorus will be downhill and become the apex of the stomach funnel In many cases, the vertebral column projects so much above the pouch of the posteriorly placed fundus of the stomach,

that the patient must be turned in the semi-prone or prone position thus throwing the mobile balloon filled with mercury against the anterior wall of the stomach and toward the pylorus

The observations of Cannon that solid objects forced against the pylorus prevents relaxation of the sphincter and retards the passage of the liquid gastric chyme accounts for the inability to pass some of the intestinal tubes with metal tips and bulky heads. In the simplified intestinal decompression tube with the liquid mercury trapped in the loose sac the pylorus is presented with a mushy sac. This has the consistency of a thickened chyme. As a result it more nearly approaches normal physiological conditions and hence passes through the pylorus more readily

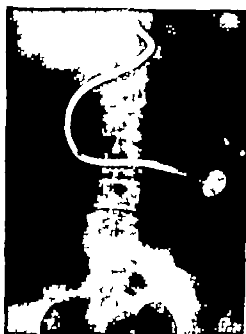


Figure 36. Four hour film after intubation. The effect of giving the patient 10 drops of dilute hydrochloric acid in two ounces of water every two hours and orange juice in the same amount at the same time.

The fact that liquid food may be forced into the duodenum in a few minutes and the observations that carbohydrate foods leave the stomach very shortly after ingestion whereas protein and fats take much longer is also utilized to insure successful intubation in difficult cases If the tube fails to pass through the pylorus in the first twelve hours the patients are given small amounts of liquid chiefly water and orange juice as well as karo sweetened water in an effort to utilize this fundamental observation Success has often followed this procedure in otherwise troublesome cases Cannon s observations that hydrochloric acid in the stomach favors or produces a relaxation of the pyloric sphincter may similarly be utilized by giving the patient ten to twenty drops of ten percent hydrochloric acid in one half glass of water and clamping the tube for one hour With pyloric



Figure 37 Tube has passed through the gastro-intestinal tract and head found at the ileo-caecal valve at operation. Note how almost the entire small bowel pleats itself upon four feet of intestinal tubing

relaxation and the patient in the proper position the tube head will invariably pass through Once the tube head is through the pylorus the hydrochloric acid must be discontinued as acid in the duodenum causes contraction

When the intestinal tube has passed into the duodenum, usually its downward progress is rapid regardless of the type of tube used The air filled balloon double lumen tubes, being based upon the principle of downward propulsion by peristaltic waves, may move with difficulty in paralytic ileus We have been much more successful since we have used the simplified intestinal decompression tubes in such cases At times, the angulation created at the duodeno-jejunal flexure due to a distended jejunum and collapsed duodenum with a short ligament of Treitz may create a barrier to successful intubation This is less likely to occur with the simplified intestinal tube although on occasion no tube will pass this point Adequate jejunal decompression is obtained, however so that in a few days conditions are favorable for the further downward progress of the tube As long as the patient is decompressing and his abdomen becoming clinically flatter and softer a waiting policy will bring rewards in successful intubation This of course does not apply to strangulating or suspected strangulating obstructions— in these cases immediate surgery is the rule

In the small bowel the mechanism of propulsion of the bolus of food or the bolus of the tube head is contraction behind the bolus with relaxation in front of it. This mechanism is further complicated by the attempt at segmentation of the bolus of food thus creating a rather complicated mechanism In intestinal distention, the normal physiological mechanism is interfered with. Its return upon decompression of the distended loop of bowel results in the initiation of peristalsis and the down progress of the intestinal tube In cases of paralytic ileus much less return of peristalsis is found with the result that intestinal intubation is more difficult. It is in cases such as these that motion of the patient in many directions is utilized to pass the simplified intestinal decompression tube by virtue of the effort of the mercury in the head to always run downhill decompressing the distended loops of bowel along the way

When the tube head reaches the colon, usually it matters very little for purposes of decompression whether it goes any further Most of the distention of the small bowel will have been cleared up The liquid content of the right colon is amenable to aspiration through an eighteen-french tube, but the solid feces of the left colon is not The gastro-colonic reflex is utilized as is ambulation if colonic intubation is desired. It is well known physiologically that the right half of the colon triturates intestinal content but that upon the ingestion of food a reflex is set up that causes mass *peristalsis that moves the intestinal content of the right* colon and the tube head into the transverse colon These movements are strong peristaltic movements but occur only three to four times a day For this reason, it may take two or three days to intubate the left colon *Because of the solid nature of the contents* of the left colon a transverse defunctionizing colostomy is an excellent procedure for colonic decompression except in those cases of incomplete obstruction of the left colon on an inflammatory basis In that event, long intestinal tube intubation is quite successful until the inflammatory reaction subsides releasing the obstruction.

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CHAPTER I

DISTENTION IN THE GASTRO-INTESTINAL TRACT

IT IS a well established fact that the control of distention is a cardinal point in the treatment of intestinal obstruction. Our newer methods of treating intestinal distention by intubation has been one of the greatest factors in reducing the mortality rate from sixty percent to less than sixteen percent Our knowledge of water balance as well as the numerous contributions to our knowledge of intestinal physiology and physiological chemistry coupled with the use of sulphonamide compounds and more recently penicillin also played a role in reducing this mortality rate.

In discussing intestinal distention it must be borne in mind that there are all degrees of intestinal distention from the mild post-operative distention to the most severe type found in a neglected case of intestinal obstruction. The phenomenon of intestinal distention is an invariable accompaniment of any interference with the normal passage of intestinal contents from os orum to os anum Once there is an interference with the free movement of the intestinal stream some degree of distention is almost certain to follow

The milder forms of intestinal distention found so commonly post-operative are generally accepted as being due to swallowed air Although the recent work of Ringsted and Andersen[129] McIver[130] and Fine[131] has called to the attention of the surgical world that seventy percent of the gaseous element found in intestinal distention is due to swallowed air yet medical interest in this problem has been traced back to the time of Hippocrates The earliest written work on this subject was a book on the winds or flatuosities written by Hippocrates As a result the ancients created an entity of the condition to which they gave

the name 'morbus ructuosus' and ascribed all sorts of disorders to it.

Kantor[132] in his excellent review of the literature of this subject has traced the numerous publications from the earliest times to the year 1918. I shall quote freely from his article on the subject which was so well done that it could not be improved upon. From this review, we find that Combalusier, in 1747, attempted to give a more restricted significance to the role played by the gases. Although as far back as 1652, a study of the intestinal gases had been made by Van Helmont it was not until the end of the eighteenth century that the indefinite notion of morbus ructuosus was abandoned and that interest was centered on the actual composition and origin of the gases. As material, both human and animal, accumulated, the true nature of the gases began to be understood. Human subjects were examined after death, criminals being the chief subjects. Despite the crude methods employed at that time, the basis for the chemistry of the subject was really laid down in these investigations. Magendie[133] gave us the first clear account of air swallowing in 1813. He reported the case of an army conscript who practiced auto-inflation to avoid military service. The experimental contributions of Latour,[134] Tappeiner[135] Schierbeck,[136] Woodyatt and Graham[137] and Yllpo[138] tended to show quite well that the basis of gastric gases under normal conditions is constituted of atmospheric air.

Despite the work of Magendie showing that air swallowing was not uncommon and was a perfectly normal physiological process, it was never fully realized that air swallowing under pathological conditions may give rise to disturbances generally assumed to be due to gases arising within the body.

It was not until the publication by Quincke in 1889[139] and by Bouveret in 1891[140] that the present view point was given complete expression. Bouveret's term aerophagia was immediately accepted and confirmatory papers followed each other quickly. Although it was readily accepted that air was constantly being swallowed by normal individuals it was not so widely accepted that the gases of the stomach were derived entirely from the atmosphere.

The fate of the atmospheric air that is swallowed and appears

in the stomach in the normal individual is well known Most of the swallowed air escapes through the esophagus by eructation This is a reflex, and occurs when there is an increase in the intra gastric pressure Some of the gas passes through the pylorus and moves downward in the gastro-intestinal tract A portion of this gas is excreted per rectum and a portion of it is absorbed by the mucosa That oxygen is readily absorbed by the gastric mucosa is an old observation. Yllpö[141] has shown that oxygen is absorbed by the gastric mucosa at the rate of twelve cubic centimeters per minute. It is therefore probable that whatever gas is passed into the small intestine at the end of the ordinary period of digestion consists chiefly of nitrogen with some carbon dioxide from the stomach. In the fasting stomach whole atmospheric air may pass through the pylorus. Analysis of the gas found in the gastro-intestinal tract by Ringsted and Andersen[142] shows nitrogen 68%, oxygen 20% and hydrogen and methane 12% Transection experiments in which the esophagus was tied off and then a bowel obstruction produced in experimental animals has shown well that little or no intestinal distention resulted This emphasizes the great importance of swallowed air in the production of intestinal distention when the bowel is obstructed Not all of the gas found in the gastro-intestinal tract, however, is the result of swallowed air The two other sources of gas in the gastro-intestinal tract are gaseous interchange with the blood circulating through and to the bowel wall (20%) and the action of intestinal bacteria upon the bowel content with the formation of gas (10%)

Although the three sources described are considered as being the cause of the gaseous distention in the gastro-intestinal tract, the percentage of gas formed from each source varies with the etiological factor responsible for the intestinal stasis For example in the post-operative type of intestinal distention the gas is chiefly swallowed air and very little of the intestinal gas is *due to diffusion from the blood vessels in the bowel* wall and none is due to intestinal putrefaction or fermentation. Such types of intestinal distention although annoying to the patient and surgeon are not generally of serious moment and can usually be controlled by an indwelling duodenal tube of any type The more severe forms of post-operative distention however are to be

classified with the type of distention as a result of a true bowel obstruction

Gaseous distention of the gastro-intestinal tract varies greatly in degree and in composition depending upon the cause of the interruption of the intestinal stream and also depending upon the point in the gastro-intestinal tract at which the interruption occurs Generally obstruction to the intestinal stream may be produced in three different ways Mechanical occlusion of the bowel either from without the lumen, within the lumen of the bowel, or from within the wall of the bowel Diminution or loss of intestinal peristalsis from any cause whatever Interference with the blood supply of the bowel which may be primary or secondary to any of the preceding forms of interference with the intestinal stream Any one of these factors may operate independently or in combination to produce intestinal stagnation which results in distention Intestinal distention although an almost invariable accompaniment of this stagnation, does not always occur with bowel obstruction Obstructions high up in the gastro-intestinal tract produce very little distention for the obvious reason that there is very little bowel proximal to the intestinal blockage to become distended Naturally, the degree of intestinal distention increases as the point of intestinal blockage passes downward to the anus, and the greatest degrees of intestinal distention would as expected occur with lesions of the sigmoid colon

In contra-distinction to most cases of early post-operative distention in which the distending element is chiefly swallowed air, in the vast majority of cases of bowel obstruction the distending element is not only gas but large amounts of fluid and particulate matter The fluid content of the distending element in the gastro-intestinal tract may equal or exceed the gaseous This fluid is derived from three main sources (*a*) that liquid ingested by the patient and carried down the gastro-intestinal tract to the area of bowel blockage (*b*) saliva gastric juice, pancreatic juice, bile, and succus entericus—3000 c c secreted daily (*c*) fluid from the blood vessels of the bowel wall passing into the bowel The only constant of this triad is the fluid secreted by the patient The greatest source of fluid within the bowel in obstruction is thought to come from the circulating blood and is characteristically

cury will provide a fairly good blood flow through the bowel wall If the diastolic blood pressure drops to 50 mm of mercury, then the blood flow through the bowel wall will not be continuous and may even cease when the pulse pressure drops as a result of a bowel obstruction Gatch Trusler, and Ayers[149] have observed that there is always some flow of blood which no degree of intra intestinal pressure will stop They attribute this to a small anastomotic artery at the mesenteric border of the bowel. This explains the maintenance of the flow of blood through the mesentery when the circulation through the intestine is arrested by distention.

Stone and Firor[150] have recorded measurements of intra intestinal pressure varying from thirteen to one hundred and eleven mm of mercury Sperling, Paine, and Wangensteen[151] have reported the rupture of a distended loop of bowel on its escape from the abdomen They found by experiment that a piece of fresh human ileum ruptured at a pressure of 210 mm. of mercury Except for extremely high pressures the intra intestinal pressure is no measure of the impairment of circulation. Gatch and Battersby[152] have shown that a pressure high enough to put the wall of the bowel under tension will decrease in the course of a few hours because of dilation of the bowel In such cases the color of the wall of the bowel and its degree of tensity clearly shows whether the pressure is injuring it. They have demonstrated in dogs that an intra intestinal pressure great enough to cause tenseness of the wall of the bowel will slowly decrease as the bowel dilates and becomes flaccid A tense bowel has a diminished blood flow but that when it becomes flaccid there is sufficient blood flow to keep it alive though it suffers from con gestion of blood in its capillaries In this way dilation protects the bowel against high intra intestinal pressure provided the pressure does not increase step by step as does the dilation. Acute and serious injury to the bowel by intra intestinal pressure occurs then only when the pressure is near the diastolic blood pressure and persists for several hours Van Zwalenburg[153] made similar observations on the blood flow in the intestinal wall as affected by varying pressures within the intestinal lumen. He noted that it was quite certain that distention of the bowel inter fered with the circulation in its wall and permitted infiltration

and effusion to take place into its wall and lumen and into any other open spaces which might come into its influence The venous circulation was shown to be retarded at comparatively slight pressures Effusion follows, as in all obstructions to venous flow Since the average venous pressure varies from four to ten mm of mercury, any pressure beyond that would offer some resistance to the return flow of blood Gatch, Owen and Trusler[151] have shown that the volume of blood flowing through the wall of the bowel decreases as the intra intestinal pressure increases, until it becomes nothing when the intra intestinal pressure is equal to the systolic pressure When the intra intestinal pressure reaches the diastolic blood pressure, then the only flow of blood within the wall of the bowel occurs during the ventricular systole. Herrin and Meek[137] in studying the effect of distention in dogs with various types of fistules have come to the conclusion that distention is a strong stimulus to intestinal secretion In this fashion a vicious circle is created

Because intestinal distention that we are concerned with in long intestinal tube intubation is the result of the accumulation of gas and fluid in different proportions the laws of equalization of pressures does not apply as it would if the distending element were either gas or fluid alone. The admixture of gas and fluid in loops of bowel lying in every conceivable plane in the abdomen and often kinked by virtue of the weight of the fluid within it necessarily decreases the efficiency of any method of suction applied for the purpose of decreasing the distention. Such kinks in the bowel are important factors in decreasing the efficiency of gastro-duodenal suction drainage and make the use of the long intestinal decompression tube imperative particularly when the kinks are maintained by the weight of overlying loops of bowel

That distention alone is capable of producing many of the symptoms and sequeli of intestinal obstruction has been well demonstrated experimentally by Fine, Rosenfeld, and Gendel[1-6] These workers demonstrated that distention without obstruction could produce dangerous effects

Recent observations by Leithauser[164a] suggests that a vitamin B deficiency particularly thiamine chloride, may be responsible for many of the cases of post-operative distention. He has re

ported six cases of adynamic ileus with severe abdominal distention to call attention to the fact that symptoms suggesting the presence of intestinal obstruction and leading to erroneous diagnoses and unnecessary operations may be caused by thiamine chloride deficiency. In these cases, the distention was not controlled by mechanical decompression nor administration of prostigmin, but responded dramatically to the administration of thiamine chloride and vitamin B complex.

Monteiro and Filho[illegible] were very enthusiastic about the use of thiamine hydrochloride in the treatment of post-operative intestinal distention. Based upon their observations of nineteen cases they have been able to demonstrate the therapeutic effectiveness of thiamine hydrochloride in the treatment of the post-operative distention particularly when it occurred in individuals with vitamin deficiencies.

When a vitamin deficiency state does not exist it seems quite doubtful as to whether any one vitamin or group of vitamins has any stimulating effect upon intestinal motility. It has been well established that a lack of certain elements of vitamin B complex will seriously impair the intestinal motility. It has also been shown in vivo and in vitro that vitamin B-1 inhibits the cholinesterase which in turn frees more acetylcholine to promote intestinal motility. Monteiro and Filho in their studies of the effect of thiamine upon intestinal distention were of the opinion that a deficiency of this vitamin resulted in degenerative changes in the plexus of Auerbach and in the nerve endings of the vagus. From its action in the treatment of intestinal distention, they formed the hypothesis that the vitamin B-1 had a healing action upon the cells and the fibers of the plexus of Auerbach and the vagus.

This experience suggests that nutritional deficiency should be suspected and a therapeutic trial of vitamins made in cases of abdominal distention in which the evidence does not justify a positive diagnosis of mechanical obstruction of the intestines. It suggests also that thiamine chloride should be administered at the time of operation to prevent post-operative distention especially in patients whose nutritional status is at all questionable or in whom there is any suspicion of liver damage. It is now our practice to routinely administer parenterally vitamin B complex

with high thiamine content to all surgical patients the day before operation and daily for three days after operation Since this has been done post operative distention has been greatly reduced in frequency

EFFECTS OF INTESTINAL DISTENTION

The effects of intestinal distention may be divided into the local effects upon the gastro-intestinal tract and the general effects upon the individual as a whole

LOCAL EFFECTS

One local effect of intestinal distention is an impairment of the primary physiological function of the gastro-intestinal tract i e., nutrition With intestinal distention there is stagnation of the intestinal stream and as a result little or no absorption of nutriment The individual as a result has lost the power to assimilate food by ingestion Gatch and Battersby have shown that experimentally the power of absorption from the gastro-intestinal tract ceases when the intra intestinal pressure equals or exceeds the diastolic blood pressure

Fine, Fuchs, and Gendel[157] in a recent experimental study of the factors causing death in cases of uncomplicated acute intestinal obstruction noted a serious and rapid fall in the volume of the circulating plasma This extreme loss of plasma occurred as a result of distention of the obstructed small intestine and continued as long as the distention continued. Evidence was obtained that intravenous plasma in amounts adequate to replace that lost as a result of obstructing and distending the small intestine confers a protective influence sufficient to markedly prolong the life of the animal This effect in prolonging life was not obtained by the use of equal or larger amounts of physiologic solution of sodium chloride Since the distention is responsible for the loss of plasma decompression should be accompanied by a retardation of the loss or even by a gain in plasma volume Clinically this effect upon the plasma volume is not noted in the early stages of the disease because of the various checks and balances brought into play by the body

When distention develops spontaneously clinically the ten

sion produced by the gas when it first enters the intestine is usually not sustained owing to absorption via the blood stream relaxation of the intestinal muscle tonus spatial re adjustments of adjacent organs and the relaxation of the abdominal wall. The flexibility of these accommodating mechanisms tends to keep the intra intestinal pressure from reaching pathological levels In addition a patent pylorus will permit the regurgitation of intestinal gas to some degree For this reason it is only when these adjusting mechanisms fail that there will be a critical loss of plasma volume such as is noted in experimental animals

The observations of Fine and co-workers,[134] and our own clinical observations, throw considerable doubt upon the observations of Elman[159] *that death can follow an adequate decompression of an acute distended bowel because of too sudden deflation.* In well over five hundred cases we have never seen this to occur In fact in late cases of bowel obstruction with tremendous distention the more rapidly the distention can be controlled the better *The removal of five to six thousand cubic centimeters of* liquid material and unmeasured amounts of gas in a twenty four hour period is not unusual

With distention as has been noted there is interference with the blood supply to the bowel wall As a result there is an increase in secretion into the lumen of the bowel and an increase in transudation from the vessels in the bowel wall. The result of this is loss of fluid, chlorides and finally plasma into the lumen of the bowel and peritoneal cavity This fluid loss is further increased by the most commonly noted sequeli of intestinal distention namely—vomiting In high intestinal obstruction with little distention vomiting is a very early finding which rapidly depletes the chlorides of the patient resulting in the development of early dehydration and alkalosis In low intestinal obstruction characterized by great distention vomiting is apt to appear late in the course of the disease. As a result the tendency toward the development of acidosis due to loss of alkali is the usual effect

It has been amply demonstrated by the preceding discussions that the degree of distention produces a directly proportionate circulatory impairment of the bowel wall Impaired nutrition to the bowel wall as a result of impaired blood supply occurs when

the pressure within the lumen of the bowel exceeds the systolic pressure and may be followed by necrosis and perforation of the gut The check mechanisms previously discussed are such that this occurrence is uncommon Intestinal distention in the degree that is found clinically although sufficient to impair the venous return because of the low venous pressure will not impair the arterial supply sufficiently to produce gangrene and perforation except in far advanced neglected cases The usual result of the venous stagnation is congestion and loss of fluid by transudation With a high degree of intestinal distention there is in addition circulatory impairment The diaphragmatic excursion is limited due to the pushing upward of the diaphragm into the thorax by distended loops of bowel The decreased negative pressure in the chest results in a loss of the sucking power into the superior vena cava and a resultant congestion of the areas which empty into it In addition the abdominal distention by pressure upon the inferior vena cava results in an impaired venous return and consequently a loss of serum into the peritoneal cavity This is further increased when the patient is put up in Fowler s position In this position the flexion of the thighs tends to decrease the venous return to the femoral veins which is further decreased by the increased abdominal pressure pushing upon the iliac veins Considerable fluid is lost to the circulation of the patient with an obstructed bowel by both methods of venous stagnation The final result of this fluid loss is dehydration

Dehydration Dehydration is one of the most important effects of intestinal distention but one which can be adequately controlled at the present time with our knowledge of fluid balance The development of dehydration and the degree of dehydration depends upon the level at which the blockage of the intestinal stream occurs The higher the obstruction the more rapid the onset and the more severe the degree of dehydration whereas the lower the obstruction the slower the onset of dehydration The sequence of events that was considered by most surgeons[150a] to result in dehydration was as follows With interruption to the intestinal stream regardless of etiology there is a stagnation of the intestinal content Gas and fluid are accumulated in the obstructed segments of bowel and involve more segments proximally

to the point of obstruction. The bowel becomes more and more distended with a resultant increase in intra intestinal pressure. With the increase in the intra intestinal pressure, there is an increased transudation of fluid into the bowel and tissue spaces *from the vessels in the bowel wall as a result of vascular compression* With this loss of fluid from the blood vessels there is a diminution in circulating blood volume This results in a loss of plasma producing a hemoconcentration. There is also a loss of chlorides which varies in degree the higher one obstructs the gastro-intestinal tract. High obstructions have the greatest chloride loss Since all the blood volume must be maintained for adequate nutrition fluid is drawn into the circulation from the tissues and water depots of the body to replace that lost into the bowel Very soon the tissue fluid is depleted with the resultant development of dehydration phenomenon.

As opposed to the previously held views noted above the observations of Fine and associates[180] tended to show that bowel distention maintained for many hours causes marked concentration of the blood. They state that this cannot be explained by *dehydration or by intra-peritoneal loss of fluid. Gatch and* Battersby[181] in their experimental work in dogs appear to have demonstrated that the hemoconcentration which occurs as a result of intestinal distention is due to the injury to the capillary endothelium throughout the body as a result of asphyxia Because of the slowly developing asphyxia resulting from intestinal distention there is damage to the capillaries throughout the body resulting in a loss of albumin chiefly and globulin to a lesser extent. They claim as proof to corroborate this experimental finding that artificial respiration and giving pure oxygen to the patients (or *experimental animals) would oppose the development of the* dehydration phenomenon because of its effect upon the asphyxia Both these measures mitigate but do not prevent the asphyxia. The observations of Fine, Frehling and Starr[182] upon the effect of giving pure oxygen to animals with intestinal distention indicates that there is a decline in the intra luminal pressure which *consists chiefly in a washing out of the nitrogen This may be* responsible for some of the good results obtained by Gatch and Battersby

A loss of chlorides into the bowel or by vomiting is compensated for by a retention of sodium in order to maintain the proper hydrogen ion concentration As the loss of chlorides continues insufficient sodium is available to compensate for the chloride loss so that in order to keep the proper acid base balance sodium must be excreted by the kidneys Since sodium is responsible for water retention in the tissues a loss of sodium through the kidneys carries some water with it resulting in a further water loss thus increasing the dehydration If this process is not corrected, the interstitial fluid reserve becomes exhausted causing the cellular water to be lost This is very dangerous because of the small margin of safety permitted in the loss of intra-cellular fluid If continued cellular death occurs

Effect of Distention Upon Motility There is uniform agreement that distention of any part of the small intestine with adequate pressures results in inhibition of the small intestine both above and below the distention Youmans Meek and Herrin[102] have shown experimentally that the motility of the jejunum above and below a distention has been decreased The distention of the jejunum in a dog results in inhibition of all types of movement and decreased tonus of the undistended part of the jejunum in both directions from the site of the distention The degree of inhibition depends upon the rapidity with which the pressure is increased in the distending balloon and upon the final pressures obtained This inhibition of the jejunum is the result of a reflex over the extrinsic nerves by stimulation of the afferent endings in the jejunum by the distention When the extrinsic nerves are cut an intrinsic and less efficient mechanism for mediating intestinal inhibition during intestinal distention is brought into play This pathway is supposedly over the intrinsic nerve cells in the bowel wall

Pain and Nervous Exhaustion With increasing distention as a result of bowel obstruction, intestinal pain is one of the cardinal symptoms Where the intestinal stasis is due to paralytic ileus the element of pain may be absent but the exhaustion as a result of the infection or the etiological factor responsible for the ileus replaces it in importance With bowel obstruction intestinal colic is almost continuous and severe. Rest is obtained with great

difficulty, if at all due to the severity of the abdominal pain The intestinal contractions, in an effort to overcome the blockage of the intestinal stream, are very severe and remain so until the obstruction is relieved or the bowel so distended as to become atonic. In strangulating types of obstruction, the peristaltic waves are so violent that the pain may be almost unbearable. In late cases, this may be complicated with the development of pain due to peritonitis On the other hand, the pain may be the result of the peritoneal irritation from peritonitis and the intestinal distention be on a paralytic basis In any event, long continued pain results in a deterioration of the physical condition of a patient already dehydrated and taxed with the primary lesion producing the obstruction Physical exhaustion or shock resulting in death may be the result The pain stimuli from a strangulated bowel may be so severe as to produce a shock phenomena to some degree

Role of Distention Upon Vomiting The vomiting associated with any interruption of the intestinal stream is directly related to the distention This vomiting may be produced as a result of two distinct factors On the one hand there may be vomiting of reflex origin and on the other the vomiting due to the mechanical obstruction to the normal passage of intestinal contents.

Best and Taylor[164] describe the reflex vomiting as being the result of the stimulation of afferent receptors in the bowel wall as a result of the intestinal distention The impulses from these receptors in the bowel wall are relayed centrally by splanchnic afferent fibers to the vomiting center in the medulla. Stimulation of this center results in efferent impulses being sent out from the center over autonomic and by means of rami communicantes to cerebro-spinal nerves producing the vomiting As long as the impulses continue to be carried to the medulla from the bowel wall the vomiting continues and is only relieved by a release in intestinal distention

In addition to the reflex origin of the vomiting with intestinal distention there is a definite mechanical factor It is quite obvious that any interference with the normal downward movement of the intestinal stream must result in intestinal stasis This stasis occurs regardless of the cause of the bowel obstruction or regard

less of the etiology of the interference with the intestinal stream Stasis of the intestinal stream results in intestinal distention varying in degree with the point at which the interference occurs The higher the obstruction the less the distention whereas the lower the obstruction the greater the distention Regardless of the degree of distention the intestinal stasis always occurs With intestinal stasis, vomiting may occur in one of two different ways We have always been under the impression that a reversal of peristaltic waves was possible and was responsible for the vomiting of the liquid intestinal contents created by the intestinal stasis Johnston[103] has advanced the hypothesis that reverse peristalsis never occurs but that the vomiting is in reality due to a reversal in the direction of flow of the intestinal contents by a sort of reflux mechanism This would be brought about by the contractions of the bowel upon the intestinal contents forcing this liquid material against the point of blockage Since the intestinal content cannot get through, it rebounds and creates a reversal of the current resulting in vomiting Whatever the exact mechanism one cares to subscribe to the fact remains that any interference with the normal downward movement of the intestinal stream results in a reversal of this intestinal stream causing vomiting

The vomiting in high obstructions is generally a very early symptom and one which in a short period of time results in the development of dehydration from fluid loss and alkalosis from chloride loss This eventually results in renal failure nitrogen retention and death The vomiting in low intestinal obstructions does not come on so early in the disease and is usually not so severe until quite late in the obstructive process Alkalosis does not occur because there is no loss of chlorides immediately Instead acidosis is the usual accompaniment With all types of vomiting both water and electrolytes are lost to the body Dehydration and the dangerous sequeli resulting from it may result

Crowley[106] has described another reflex effect of intestinal distention. This is the effect of distention upon respiration and blood pressure exclusive of the interference with diaphragmatic excursion. It has been shown that excessive intestinal distention suddenly induced is capable of producing in experimental animals, even when anaesthetized marked variations in blood pressure

and respirations These changes persisted for as long a time as the intestinal distention which initiated them continues Crowley is of the opinion that these respiratory and blood pressure changes are the result of some obscure reflexes from the bowel wall. The stimuli to afferent endings in the bowel wall relay impulses via the splanchnic nerves to the respiratory and blood pressure centers in the medulla From these efferent impulses sent out by way of the autonomic nervous system which sends communicating rami through the cerebro-spinal nerves produces both respiratory and blood pressure changes These changes are of a characteristic pattern and are accompanied by synchronous fluctuations in the blood pressure Crowley suggests that some of the shock like syndromes that occur with bowel obstruction may be caused in this way Clinically, the rapid advent of shock phenomenon in any patient with a strangulating obstruction or one in whom the mesentery is twisted tends to lend corroborative support to this idea There is insufficient experimental corroboration to make it more than a theory as yet

EFFECTS OF DISTENTION UPON THE BODY AS A WHOLE

The effect of intestinal distention upon the circulatory system is to produce some degree of venous stasis and as a result tissue anoxia This is inevitable when one considers the fact that the entire portal venous circulation becomes stagnant as a result of the pressure of the distended bowel upon the veins in the bowel wall Sperling[167] has shown that a sustained intra luminal pressure of fifteen centimeters of water is capable of injuring the bowel wall through venous stasis With venous stasis, not only is there an impaired nutrition because there is impaired absorption but in addition the bowel wall becomes permeable to bacteria Mahoney et al [168] have shown that placing succinyl sulfathiazole in closed loops of bowel prolongs survival rate greatly This strongly suggests that bacterial products may be a factor in cases of intestinal distention If the arterial supply is interfered with by the increased intra intestinal pressure, necrosis of the bowel occurs, resulting in perforation and peritonitis

In addition to the immediate effect upon the vessels in the bowel wall the intestinal distention by producing an increase in intra abdominal pressure causes pressure upon the inferior vena

cava and iliac veins. This results in a further tendency to venous stasis. In addition the limitation of the free downward movement of the diaphragm decreases the negative pressure in the thorax by means of which the venous return to the superior vena cava is sucked into the right auricle. Here again, we have an increase in venous stasis. With venous stasis we have tissue anoxia throughout the body and as a result of tissue anoxia a general deterioration of all body physiological processes occurs.

That the intestinal toxaemia produced as a result of the bowel obstruction may play a role in this general deterioration of the physiological processes of the body is strongly suggested by the work of Blain and his co-workers.[169] This work done upon experimental animals shows that by keeping the bacterial flora at a low level the life of the animal was markedly prolonged. This work and that of Poth[229] suggests that our old idea of intestinal toxaemia, which was discarded, may have some basis in fact and although not the main factor in producing death of the individual may nonetheless be a contributing factor. It further gives us a new aid in our treatment of bowel obstruction.

Davis, Gaster, Marsh, and Pritel[229b] studied the effect of streptomycin in experimental strangulation of the bowel in rabbits. They were able to demonstrate that the mortality rate was lowered by injecting the rabbits with 40 mmg. per kilogram body weight and that by the use of 100 mmg. per kilogram body weight that there was a definite prevention of mortality in the rabbits subjected to experimental strangulation of the bowel by devascularization. In their studies it was found that bacterial growth in the devascularized bowel wall was the major factor leading to perforation and gangrene of the bowel. Prevention of the growth of bacteria by streptomycin was the mechanism underlying the prolongation of life in the treated rabbits in these experiments.

On the basis of the results obtained by Davis et al. as well as those obtained by Blain, and Poth and Knotts and numerous other workers, it would appear that in human beings that the administration of streptomycin, penicillin, or the various intestinal sulfonamides might be a useful adjunct in the treatment of strangulating types of intestinal obstruction. These antibiotics (streptomycin and penicillin) can be given in intestinal distention when strangulation is suspected while the patient is being prepared for

operation. Under no circumstances should these newer antib
terials ever be used to avoid operation.

The effect of intestinal distention in the production of
hydration has been touched upon in a previous section. The eff
of this dehydration and plasma loss created by the intestinal d
tention is to produce hemoconcentration. As a result, there is
alteration in the hematocrit, blood count and a change in t
entire physiological chemistry of the blood. Hemoconcentrati
means a decrease in the amount of water available for excreti
by the kidneys. When this is permitted to reach a point at whi
less than five hundred cubic centimeters of urine is excreted dai
nitrogen retention by the kidneys occurs. If unchecked uraem
and death result.

Kaufman and Vom Saal[1 4] have reported upon the wh
blood counts of patients with various intra abdominal diseas
They found that a marked neutrophilic shift to the left may occ
in all types of acute peritoneal irritation even without infectio
This depends upon a sudden peritoneal shock or irritatio
Van Duyn[17] has also noted a degenerative blood picture to occ
with distention of the small bowel as well as in obstruction
the colon. The same picture occurred regardless of whether t
distention was paralytic or mechanical and in the absence of a
evidence of infection. These findings help to confirm the fa
that intestinal distention in itself may be the cause of the degene
tive blood picture. The actual mechanism is thought to be
inhibition of the hemopoietic function of the bone marrow
some toxic substance apparently non-bacterial in origin and po
sibly absorbed from the distended intestine. The effect of th
hypothetical toxic substance upon the leukopoietic system is pure
inhibitory and is not due to overstimulation such as occurs at tim
from overwhelming infection. Whatever may ultimately prov
to be the cause of the marked neutrophilic shift to the lef
whether it be intestinal distention, peritoneal irritation or som
other factor, its importance lies in the fact that it can occur an
must not be considered as being due to the development of infe
tion. This pure degenerative blood picture described by Van Duy
as it occurs in intestinal distention is characterized by: low t
leukopenic white blood cell counts, normal to neutropenic neutr

phil percentages absence of myelocytes normal to increased per centages of lymphocytes and monocytes and the presence of eosinophiles

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CHAPTER VI

INTESTINAL DECOMPRESSION TUBES IN USE TODAY

THE only intestinal decompression tubes used today in the treatment of intestinal distention are the Levin tube or modifications of it, the Miller Abbott tube, the Johnston tube, the Harris tube the Aguiar and the Cantor tube Each of these tubes was designed and developed to satisfy certain criteria that the surgeon thought necessary in order to insure intestinal intubation and induce adequate decompression. Just as it was noted in the section on the history of intubation that the development of the tubes went hand-in hand with the need for such tubes so also did the development of these different types of long tubes arise to satisfy the needs of the surgical world to treat intestinal distention better than heretofore

Although the Levin tube is included in this section, it is in reality not an intestinal decompression tube but rather a gastro-duodenal tube In 1921, when Levin[172] introduced his tube it was designed specifically for gastric and duodenal intubation studies and treatment It was utilized by Ward Kanavel and Wangensteen as a means of securing intestinal decompression either by siphonage or suction. The early studies by Wangensteen and Paine[173] did much to popularize and emphasize the value of such intestinal decompression in the treatment of intestinal distention In the treatment of the intestinal distention characterized chiefly by the accumulation of gas in the bowel such as is seen in post-operative distention the results of this form of treatment were excellent. The reason for this was obvious since it was unnecessary for the tube to pass down the gastro-intestinal tract because the gaseous distention was readily removable by decreasing the gaseous pressure proximally It was soon noted however that in a large percentage of cases quoted (from thirty to forty

per cent),[174] that the tube did not pass through the pylorus The result of this was that liquid elements beyond the upper jejunum could not be removed readily To overcome this shortcoming the end of the tube was impregnated with lead to weight it and so insure its passage through the pylorus [175] Although this was accomplished in some cases still the percentage of failures was in the neighborhood of thirty per cent Again, we find the element of weight being used to pass this tube through the pylorus and again we find the results not too good This may be connected with the earlier observations of Cannon that the pylorus will not relax when pressed upon by a solid object such as a tube Paine,[176] in a paper entitled *The Hydro-Dynamics of the Relief of Distention in the Gastro-Intestinal Tract by Suction Applied to Inlying Catheters* was able, by clinical observations in over two thousand patients, as well as by animal experimentation, to reach certain conclusions He noted that siphonage as used at that time was far less efficient when used with the Levin tubes than was constant suction The fact that bubbles of gas would break the siphonage stream necessitating a repriming was the answer It was further found that suction applied to a gastro-duodenal tube would not bring the pressure in the terminal ileum to zero in experimental animals although there was some reduction in intraluminal pressure along the ileum He concluded that while suction, when applied and maintained through a gastro-duodenal tube (Levin) was highly efficient in decompressing the stomach alone, it was necessary to insert the tube through the pylorus into the duodenum to obtain satisfactory decompression of the small bowel The explanation which is



Figure 39 The Levin tube or modifications of it have been used for gastro-duodenal suction drainage As can be noted, it is a simple tube of rubber and the 16 Fr size is generally employed. There is no propulsive mechanism in this type of tube. Impregnation of the end of the tube with lead (Wangensteen) serves to weight it and to facilitate its passage through the pylorus.

advanced to explain the decompression obtained when the duodenal tube remains in the stomach is to be found in the rhythmic contraction and relaxation of the pylorus During the period of relaxation, gas can be drawn up into the stomach by suction Paine notes that numbers of cases have been seen clinically in which it required twelve to thirty six hours to pass the duodenal tube through the pylorus with little or no decompression during this period of time

In the use of this gastro-duodenal tube for the treatment of intestinal distention the mechanism is essentially as follows The negative pressure at the end of the tube created by suction causes the bowel wall about it to collapse. Then if peristalsis forces gas up into the collapsed segment of bowel decompression occurs Consequently the best results were obtained where there was peristaltic activity and the poorest results were obtained in attempts to decompress an established distention due to paralytic ileus Paine used a wide range of negative pressures and found that the only contra indication to high suction pressures was the collapse of his rubber tubing and not injury to the bowel. In no case was necrosis of the bowel wall as a result of sucking of the mucosa into the openings of the tube noted either in experimental animals or at autopsy

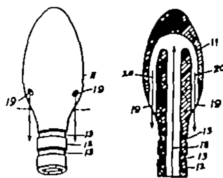
When the gastro-duodenal tube was used in the treatment of intestinal distention due to gas as well as liquid, it was found that a definite decrease in the efficiency of the tube resulted Since in most cases of intestinal stasis that we are called upon to treat, the gastro-intestinal tract is filled with varying proportions of gas and liquid the mechanism of deflation by the tube is somewhat changed With the fluid in the bowel the loops of intestine come to lie in every conceivable plane giving rise to different hydrostatic pressures. The presence of water hose kinks in these loops of bowel tends to create multiple short loop obstructions instead of one continuous passageway Such kinks once formed are maintained by the weight of overlying loops of bowel and constitute a real block to the equalization of hydrostatic pressure by suction proximal to it. With suction the elasticity of the bowel causes it to contract adjacent to the point of suction as soon as the gas and fluid in the loop are removed When this happens, decom

pression ceases, until peristalsis or manipulation partly redistends the collapsed portion of bowel In this way the tube can only act by a reflux of the intestinal stream While the duodenal tube is in the stomach it causes the walls of the stomach to collapse as a result of the negative pressure within and compression by the abdominal pressure from without With the walls of the stomach collapsed the only decompression obtained occurs when regurgitation of duodenal contents takes place through a relaxed or atonic pyloric sphincter Since in early post-operative distention the greatest source of the distention is swallowed air, the gastro-duodenal tube by preventing this component adequately prevents any aggravation of the condition The mode of action of this tube then depends upon a reflux of intestinal contents and is directly opposite from the normal we wish to attain Our experiences with gastro-duodenal suction has been much like that of Paine that many cases are greatly benefited but that in those cases in which there is the greatest need as in paralytic ileus the results were poor For this reason we use the gastro-duodenal tube (Levin) in all cases of early post-operative distention in which the distention is chiefly gaseous We believe that its greatest field of usefulness lies in such conditions and reserve the long intestinal decompression tubes to treat all other types of intestinal distention or bowel obstruction

Because of the limitations of the Levin tube in the treatment of intestinal distention as found in bowel obstruction longer intestinal decompression tubes were devised The idea being to get our negative suction pressure down to the point of obstruction and producing our suction at the bottom of our column and not by skimming it off the top as with the gastro-duodenal tube In addition, by the use of the long tube it is possible to localize the point of obstruction which could not be done by the Levin tube and last but not least since the observations of Sperling[177] upon competence of the ileocaecal valve it was obvious that the gastro-duodenal tube was of no value whatever in the treatment of distention of the colon except by preventing further swallowing of air Our long intestinal decompression tubes invariably pass down to and often through, the ileocaecal valve Many disorders of the colon can now be well handled by intestinal intubation using

these long tubes as well as aiding in facilitating colonic surgery

Four different propulsive principles are utilized by different workers who designed long intestinal decompression tubes Each man designed a tube to satisfy the physiological principle by which he thought the tube was carried downward into the small intestine These principles are the principle of "jet-propulsion the principle of peristaltic activity as activated by an inflated air filled balloon the principle of weight and the effect of gravity upon it, and the principle of a "free flow' of a highly labile cohesive heavy metal to drag the tube downward when combined with motion of the patient



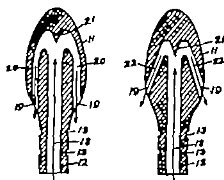


Figure 40. Aguiar Tube Head Notice two types of head for this tube. The difference in the tube heads consists in the obliquity of the emission channels. The more oblique the emission channel, the faster the tube is supposed to move down the gastro-intestinal tract.

The "jet-propulsion principle was advocated by Pavia Aguiar [178] of Brazil. This was based upon the principle that if water or any fluid was injected into the end of the tube it would shoot out through the holes at the head end of the tube obliquely to the wall of the bowel The force of this obliquely shooting water was supposed to propel the tube down the gastro-intestinal tract The speed of descent was controlled by increasing the obliquity of the channels through which the water emerges The idea being that with an increase in the obliquity of the emerging stream of water which strikes the bowel wall there would be an increase in the downward propelling force After the tube head was down the gastro-intestinal tract then the suction would be applied to decompress the patient This type of tube is not being used by American surgeons because

of our reluctance to add any fluid to a bowel that is already barrassed by being distended with gas and liquid

The Miller Abbott and Johnston tubes [179] are both based t the same propulsive principle and will be presented together tube utilizes the normal peristaltic activity of the intestinal t to propel the tube downward It utilizes the observations of I that the bowel will contract down upon a balloon inflated w it and the observations of Jones who studied pain by passi long tube tipped with an air filled balloon down the gastro-i tinal tract From these observations it was apparent that tube were passed through the pylorus and the balloon at the of the tube were inflated, that peristaltic waves would be initi which would propel the balloon tipped tube down the ga intestinal tract like a bolus Utilizing this principle the Mi Abbott tube a double lumen tube was designed to study intes physiology [180] Double and triple lumen tubes were devise Miller Abbott [181] in order to study the secretions at different l in the gastro-intestinal tract. When the need for a long was apparent in the treatment of intestinal distention bec of the failures with the Levin tube the Miller Abbott tube utilized [182]

It was soon found that using a tube of this type which w pass down the gastro-intestinal tract to the point of obstru gave far better results than did the original method of War steen using the Levin tube. Surgeons everywhere were quic see the merits of getting the tube head down to the seat o trouble and a voluminous literature resulted Because of concept of the physiological method of passage the Miller Ab and Johnston tubes were constructed with a piece of tube jecting beyond the balloon along the distal end of the shaft the tip of the tube was capped by a metal fenestrated h Johnston states that it is necessary to decompress the gu front of the balloon in order that the gut may contract upon inflated balloon which would then propel the tube down the ga intestinal tract

We very soon found that when the Miller Abbott tube used much nursing care was needed to prevent plugging of small lumen of the decompressing diameter and the small siz

the aspirating holes In addition, although the earlier reports were very enthusiastic about the use of the long tube, many reports began to appear describing the great difficulty in passing the air filled balloon tubes through the pylorus [183, 184, 185, 214, 215] In many centers a failure rate of over twenty per cent was reported [186] Johnston also used an air filled balloon as his propulsive mechanism, but to avoid the dangers of tube plugging and to provide a larger lumenal diameter for decompression he modified the Miller Abbott double lumen tube by using two tubes side-by-side and fastened together The smaller tube was utilized to inflate the balloon and the larger lumen for decompression The arrangement of the balloon along the shaft of the tube and the projection of a metal tipped piece of tubing was the same as the Miller Abbott tube because it utilized the same propulsive principle Both the Miller Abbott and Johnston tubes are calibrated in centimeters so that the intubator can check upon the amount of tubing down at any time

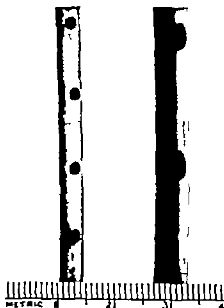


Figure 41 Notice the difference in size of the holes for decompression as found in the Cantor tube (right) and the Miller Abbott tube (left) Notice the elliptical shape of the holes in the Cantor tube This shape and size makes plugging more difficult by particulate intestinal material.

Because great difficulty in successfully passing the pylorus was noted with both of these tubes various methods were sought for to help pass the tube Some of these were very ingenious and covered a wide range of activity Most of the methods necessitated taking the patient to fluoroscopy and attempting to maneuver the tube through the pylorus under direct vision Some of the every ill patients experienced great difficulty in undergoing this ordeal

One of the methods proposed to expedite the passage of the Miller Abbott tube through the pylorus was to place a small

amount of mercury into the balloon in order to weight the head of the tube and then when the tube had passed through the pylorus to inflate the balloon as originally described and permit it to pass downward by the propulsive mechanism used by Miller Abbott and Johnston. Silvertsen[187] and Harris[188] and Wild[189] simultaneously advocated this method of weighting the balloon head. *It was soon found that this method really did expedite the* passage of more tubes through the pylorus than heretofore. But it represented a shotgun prescription of using a tube designed for air to carry mercury.

The principle of weight and the effect of gravity upon a weighted tube head was utilized by Harris[190] to devise a single lumen tube. His work with the use of mercury in the balloon of a Miller Abbott tube soon led him to the obvious conclusion that if mercury would weight the head end of a Miller Abbott tube and would carry it down the gastro-intestinal tract, possibly inflation of the balloon with air was not necessary. This was found to be the case. He soon found that mercury alone in the balloon of a Miller Abbott tube would carry the tube downward as well or better than inflating it with air. Since air was no longer required, a double lumen tube was no longer necessary. The outcome of these observations was a single lumen tube. The Harris tube is a single lumen 16 Fr. tube with a balloon along the shaft at the distal end of the tube and the end of the tube open. Two metal sleeves are inserted at the ends of the balloon within the lumen of the tube. The principle utilized by Harris is the effect of gravity upon a *mercury weighted head* as well as *the effective* peristaltic propulsion of this head. Being a single lumen tube the dangers of plugging were much less than the Miller Abbott tube. Many surgeons experienced much the same difficulty in passing the Harris tube as they did with the Miller Abbott tube. This is quite understandable when it is noted that the construction of the tube head of the Harris tube is exactly the same as that of the Miller Abbott or Johnston tubes.

It should be quite evident that only the head end of the tube constitutes the propulsive mechanism since all tubes beyond the head are merely a piece of rubber tubing. Since the head end of the tube is its propulsive mechanism, it should be noted that

variations in intestinal tubes are merely due to variations in the construction of the head By placing the balloon along the shaft of the tube exactly the same construction is utilized in the Harris tube as found with the double lumen tubes The result of this is that weight of mercury is used as a propulsive mechanism in a design of tube made for air propulsion It must be noted that

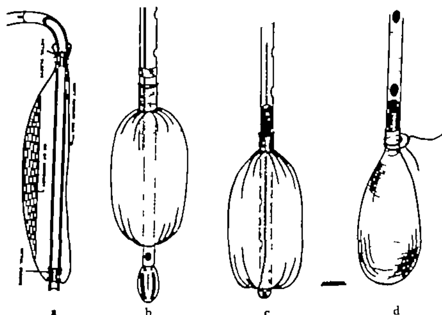


Figure 42. Tube heads of the most commonly used intestinal decompression tubes. (a) Harris tube. (b) Johnston tube (c) Miller Abbott tube. (d) Cantor tube. The Johnston tube and Miller Abbott tube are double lumen tubes. Note position of balloon along the shaft of the tube These tubes were designed for inflation of the balloon with air to propel the tube. Note the construction of the Harris tube head. It is exactly the same as the Miller Abbott and Johnston tubes. It is a single lumen tube and uses mercury as a weight Note that in the Cantor tube the loose balloon at the tip of the tube permits an unrestricted free flow of the mercury

although reports throughout the country stress the great difficulties so often encountered in passing tubes of these designs, yet the originators of the tubes have been very successful in their passage It is quite understandable that surgeons trained in the technic of intubation would enjoy greater success than the average surgeon Johnston [100] has reported almost one hundred per cent success in the passage of his tube and one of Miller's associates has informed me that at Miller's clinic that almost one hundred per cent of the tubes introduced were successfully passed through

the pylorus Our experience and that of a great many men throughout the country however, has been less happy

The principle of "free flow" of a mobile cohesive heavy metal confined in a loose balloon tipped tube is responsible for the development of the Cantor tube It was felt that mercury in itself, if given a free range of motion, would effectively carry the tube head down the gastro-intestinal tract either with or without the aid of peristalsis For this reason, a tube was designed specifically to carry the mercury and depending upon the utilization of all the physical properties of the mercury for successful intubation This tube was designed solely as an intestinal decompression tube and not to study intestinal physiology For this reason a larger lumenal diameter than ever before was used In addition an effort was made in designing this tube to satisfy four criteria for successful decompression These are (*a*) the ability of the surgeon to introduce a tube of soft radio-opaque rubber far down the gastro-intestinal tract (*b*) to decompress the bowel adequately this tube must have a lumen sufficiently large that the gases and small particulate matter found in the gastro-intestinal tract could easily be suctioned out and yet the tube not become plugged (*c*) there should be a sufficient number of holes along the tube so that the gastro-intestinal tract could be decompressed all along the course of the tube (*d*) the holes should be sufficiently large that the danger of it becoming plugged would be reduced to a minimum

By the use of such a tube it was felt that we could readily decompress the gastro-intestinal tract when an adequate source of negative pressure was used at the proximal end of the tube With these facts in mind we constructed a single lumen tube of eighteen-french lumenal diameter and tipped with a very loose balloon The tube is strongly radio-opaque so that the roentgenologist can tell us exactly where the tube is at all times and whether there is any kinking or knots or coiling of the tubes The tube was calibrated in such a fashion as to make it almost "fool proof" The first marking is S This marking placed 17 inches from the balloon end of the tube When this marking appears at the nose the tube head will always be in the stomach There will be no coiling of the tube however because the average distance

from the external nares to the fundus of the stomach is a seventeen inches In order to pass the tube through the pyl a second marking 'P' was made six inches beyond the 'S' m ing With the 'P' at the nose there is now sufficient tubin pass through the pylorus but not enough to coil in the ston The third marking is D which is made six inches beyond P When the marking appears at the nose the sufficient tubing to carry balloon head through the denum From that poin the tube is calibrated in

After much experime tion it was found that a loon two and one half in long and one and one inches in diameter was the timum size to hold the m cury A smaller balloon wo not permit a free flow of mercury and a larger ball would permit knotting of loose balloon about the because it would swing aro a loop of tube This wo occur when too much tul was passed into the stom and if the balloon was long

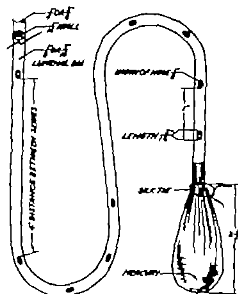


Figure 43 Cantor tube Note the series of holes along the shaft of the tube Note the large luminal diameter—18 Fr Plugging of a tube of this type is very unusual. We no longer place the tie just below the end of the tube as shown in this diagram instead we tie our tube off on the shaft of the tube over the point of attachment of the balloon. Before tying off the end of the tube tightly insert the stylet of a 21 or 22 gauge needle through the last hole into the balloon. Then tie as tightly as possible using a twenty five pound pull fishline *over the stylet within the end* of the tube. Upon removing the stylet a minute "safety valve" opening is left in the tube for the escape of gases but the hole is so small that the mercury cannot escape

In order to successfully tubate with this type of t one must remember that *are utilizing the physical pr* erties of a mobile cohes heavy metal which runs fre with any movement of the tient and always tends to s a most dependent level By combining motion of the patient and

knowledge of anatomy which permits us to maneuvre the patient in such fashion that the spot to which we want the tube head to go will always be downhill successful intubation is assured If the patient has good peristalsis rapid and successful intubation always occurs In the absence of peristalsis as in paralytic ileus the technic of intubation becomes important for successful passage Since the absence of peristaltic activity constitutes one of the greatest needs for intestinal intubation some time spent in being thoroughly familiar with the various technics of intubation may mean the difference between life or death for the patient

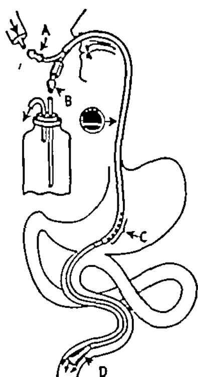


Figure 44 Abbott Rawson tube This is a double lumen tube for use after gastro-enterostomy to permit immediate jejunal feeding

In the past two years with the trend of the times popularizing the use of plastics, it was inevitable that ultimately this material would be used in tubes of various types Two intestinal tubes have been introduced which are made of plastic which has little or no tissue irritation The question of specific allergy to the plastic has not been studied as yet It may constitute a problem Although quite popular for many purposes at the present time we do not believe the plastic lends itself for use in intestinal decompression tubes Its lack of resiliency and its inability to rebound as is found in rubber tends to produce kinks far easier than in the rubber tubing Rubber tubing which has stood the test of time is much better adapted for use in the gastrointestinal tract

Of the two tubes one [220c] is a single lumen tube constructed much like the Harris tube and utilizing the same propulsive principle The second plastic tube is a double lumen tube [220d] like the Miller Abbott tube and utilizing the same propulsive principle (air-conduction) but with the balloon attached to the very

tip as in the Cantor tube which is based upon a completely different propulsive principle We have then a tube based upon two completely different propulsive principles in its construction

During the same period of time that long intestinal decompression tubes have been developed, special types of double lumen tubes for use after gastro-enterostomy came into being These tubes were developed in order that the stomach and duodenum might be suctioned out independently and in order that the stomach may be decompressed but the patient fed via the tube in the doudenum Abbott and Rawson were among the earliest workers in this special field. The first tube [225] they devised for use in the post-operative care of gastro-enterostomy cases was a single lumen tube with two valves One an inlet valve of silver so arranged on the tube that it would fall in the stomach and permit the inflow of gastric contents into the tube and a second valve at the end of the tube thirty cm beyond the stomach permitting fluids to leave the tube but not enter it These valves were mounted in 12 Fr and 16 Fr tubes This tube was abandoned in favor of a double lumen tube which was introduced in 1939 This double lumen Abbott Rawson tube [226] is a double lumened tube for one hundred cm and then a single lumen tube for the distal thirty cm. The double lumen portion is 16 Fr and the single lumen portion is 12 Fr This tube was introduced to replace the valves in the single lumen tube because the valve arrangement was unsuccessful This tube is introduced into the nose and pulled out through the mouth. Now a Lyon bucket is attached and the tube swallowed After performing a gastro-enterostomy the surgeon then slips the tip of the tube through the stoma and for thirty centimeters down the jejunum Now nutrient material can be injected into the jejunum while the stomach is being aspirated. This type of tube gives one the ability of feeding the patient on the day of operation by a more physiological means than intravenous infusion

Berk Rehfuss and Thomas [227] have proposed a double lumen tube for the simultaneous aspiration of gastric and duodenal contents Their tube differs from the Abbott Rawson tube in that a stainless steel head is used on the single lumen portion and radio-opaque bands of stainless steel as markers at the points at which

the holes were found Thus by fluoroscopy the intubator could tell exactly where his duodenal and gastric holes were

Einhorn[175] has also introduced a double lumen tube for the simultaneous aspiration of gastric and duodenal contents His tube differs from the preceding tubes in that the tube is fifty inches in length It is made of radio-opaque rubber of 14 Fr , and 16 Fr caliber The tube terminates in a catheter like tip which consists of solid lead impregnated rubber one and three fourths inches in length and of the same diameter as the rest of the tube Two slotted openings are placed just above the tip of the tube for the duodenal drainage The openings for the gastric drainage are placed as to fall in the stomach when the distal end of the tube is in the duodenum

At our hospital we have never found it necessary to use any of these gastro-duodenal tubes We use a Levin tube for the first three to five days post-operative to keep the stomach empty During this period of time most of the alimentation is given parenterally Where it is desired to give trans tubal feeding we employ a single lumen (Cantor) intestinal tube passed far down the gastro-intestinal tract There has never been any difficulty in successfully intubating these patients Atony of the distal jejunal loop following partial gastrectomy is the type of case in which such intubation has been necessary In such cases, trans-tubal alimentation may be necessary for several weeks

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CHAPTER VII

TECHNIC OF INTESTINAL INTUBATION

THE TECHNIC of intestinal intubation is variable. It depends upon the type of tube used and upon the physiological mechanism by which the designer of the tube thought it passed The technic of intubation can be described by dividing the intestinal decompression tubes into three groups (1) Air filled bal-

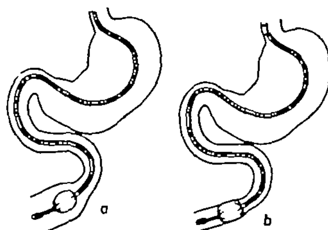


Figure 45 *From* Johnston, C. G Nelson's Loose Leaf Surgery

loon tubes (2) Air and mercury balloon tubes or mercury balloon tubes using mercury as weight (3) Free flow" of mercury in loose balloon tipped tubes.

In utilizing the air filled balloon tubes such as the Miller Abbott or Johnston tubes it must be remembered that the progress downward of the tube is based upon the concept, that the tube will not progress down the small intestine if the bowel is not decompressed (a) as it is necessary for the gut wall to approximate balloon (b) to propel tube It must also be remembered that in using this tube, purely as designed that the air filled balloon is light and floats readily in liquid The original technic of in

tubation with these tubes as described by Johnston[101] is as follows The tip of the tube is lubricated and passed into the nose until it can be felt in the naso-pharynx by the patient At this time the patient is given water to swallow to facilitate the passage of the tube into the stomach If the nasal passage of the patient

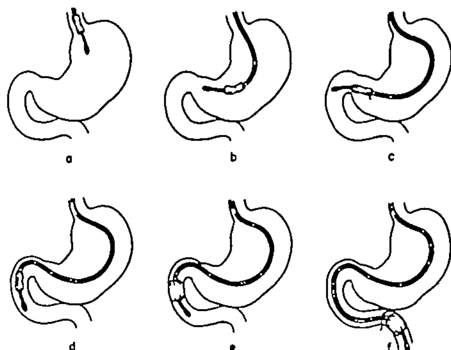


Figure 46. *From* Johnston C. G Nelson's Loose Leaf Surgery

is too small to accommodate the tip of the tube, it is necessary to remove the tip of the Johnston tube due to its size Then attach the lower end of the tube inside the lumen of a 12 Fr catheter of soft rubber which is passed into the nose. The catheter and tube are then brought out the mouth and the tip replaced Gagging during this maneuver may be minimized by making sure that the tube lies away from the center of the pharynx behind the third molar with the patient's mouth closed. After the tip is replaced upon the end of the tube, the patient is permitted to swallow the balloon in the usual fashion In using the Miller Abbott it is not necessary to remove the tip as is required at times with Johnston tube, but the tube is passed in through the nose and swallowed With these tubes now in the stomach the content of the stomach is sucked out By permitting the patient to drink

freely during the process of passing the tube into the stomach, the *stomach is also washed* In this way, particulate matter in the stomach is removed Now the tube is withdrawn until the tip lies well within the cardia This position is best determined by fluoroscopy If fluoroscopy is not available, Abbott has suggested in-

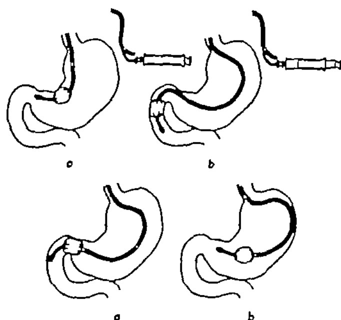


Figure 47 *From* Johnston, C. G Nelson's Loose Leaf Surgery *In the above two figures a and b, note* that with the balloon in the duodenum that it is possible to aspirate bile through the tube. This is evidence that the tube head is in the duodenum. In the two figures a and b (below) note that if the balloon is inflated with air before it has passed well into the duodenum it may snap back into the stomach and remain there.

flating the balloon with air and withdrawing the tube until the air filled balloon meets with resistance offered by the cardia This is ample evidence to the intubator that the tip of the tube is in the cardiac portion of the stomach The balloon is now emptied. The patient is now placed on his right side and the tube advanced slowly for a distance of approximately six inches The tube tip should now be at the pylorus This position is now checked by fluoroscopy because the tube may be curled in the stomach If the tube is curled or twisted upon itself it should be withdrawn until

the balloon is just distal to the cardia of the stomach and then passed again With the tube at the pylorus Johnston states, "that it is frequently possible to pass the tube directly into the duodenum " The patient is put in the supine position and the tube is advanced until it appears to turn in the stomach When this is seen under fluoroscopy withdraw the tube one inch and gently insert and withdraw at this time using only the one inch of tube This maneuver will usually pass the tube into the duodenum, then slow insertion allowing a few minutes to elapse between the introduction of each inch of tubing will advance the tip into the third portion of the duodenum With the balloon at this point it is inflated with 10 c c of air When the balloon has passed the duodeno-jejunal fold the balloon is further inflated to contain 30 c c of air In the event that the tube has not passed through the pylorus at this first attempt the patient is returned to bed He is turned on his right side and permitted to remain in that position for one hour with constant suction applied to the end of the tube At the end of one hour the balloon is inflated with 5 c.c. of air If the balloon fills easily and without tension, it indicates that the balloon is still in the stomach, but if the balloon fills under tension so that the plunger on the syringe moves with difficulty and is readily pushed out it is supposed to indicate that the balloon is in the duodenum The aspiration of golden bile also indicates that the balloon is in the duodenum The balloon should not be inflated until it is well past the pylorus or it will snap back into the stomach

When this standardized maneuver is unsuccessful in passing the tube through the pylorus the intubator may use some of the other methods advocated to insure the passage of these air filled tubes The most commonly employed of these methods are

(A) Morgenstern s method [182] This method consists in sitting the patient up behind the fluoroscopic screen The intubator then with his left hand pushes up on the greater curvature of the stomach in an effort to bring it to the same level as the pylorus, while with his right hand he passes or threads the tube head through the pylorus

(B) The stomach is inflated [183] with air through the tube and

the patient turned on his right side. Distention of the stomach now permits the tube head to be advanced to the pylorus. Johnston claims that the larger and heavier tip used in his tube permits this maneuver to be more successful because of the increase in weight.

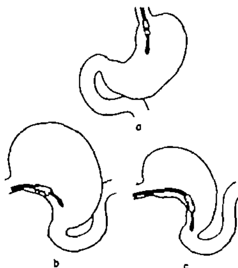


Figure 48 *From* Johnston, C. G Nelson's Loose Leaf Surgery

(C) Abbott suggests,[194] in some cases that the stomach be distended with water The patient is now turned on his left side, the balloon inflated with air, and the air filled balloon floated to the pylorus at the top of the water at the cardia of the stomach After the tip of the tube has passed toward the pylorus the water is aspirated and the balloon deflated

(D) If the transverse colon is distended preliminary passage of a rectal tube by sigmoidoscope to decompress the colon is done first and then the maneuvers as noted

(E) Abbott[195] has suggested the use of a wire stylet inserted into the lumen of the aspirating portion of the tube and passed to within six inches of the balloon Under fluoroscopic control, the stylet stiffened tube is passed through the pylorus and into the duodenum The stylet is now removed.

(F) Mayer[196] has suggested using a magnetized head made of alnico on the end of the tube The tube head is now pulled through the pylorus under fluoroscopic control using a magnet at the right flank

(G) Willson[197] uses a heavier tube of larger caliber than the Miller Abbott design. This tube is introduced with the patient either on his right side or back in the Semi Fowler's position After the tube head has left the

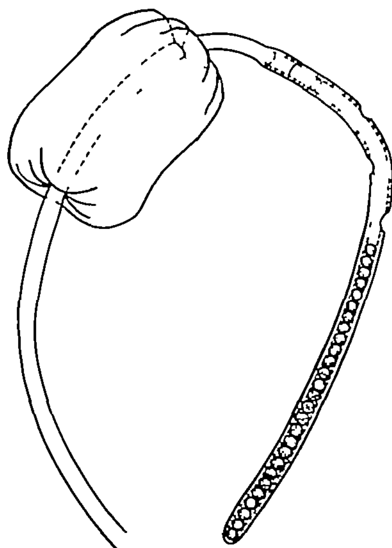


Figure 49 Morton modification of the Miller Abbott tube. Weighting a catheter with lead shot to facilitate passage through the pylorus. (*From* Morton, H B Ann. Surg., 1943)

stomach the balloon is filled with thirty c c of fluid instead of air Willson believes that the heavier tube by decreasing its flexibility is an aid to intubation

(H) Morton[198] proposes the addition of a weighted tip to the Miller Abbott tube for more successful intubation. His method is to weight five inches of the tip of a Levin tube with lead shot and then connecting this weighted tip by a short metal tube of proper caliber

to the end of the Miller Abbott tube Weight and the effect of *gravity upon it is thus utilized to aid intubation* with Miller Abbott tube

(I) Harris and Sivertsen[197] suggested the use of four to six c.c of mercury in the balloon of the Miller Abbott tube to weight the head Gravity, again, is utilized to secure intubation of the weighted head Balloon may be filled with air in some centers

The multiplicity of methods and devices utilized in order to successfully intubate with the Miller Abbott and Johnston tubes *suggests that there has been much difficulty throughout the country* in successfully passing these tubes through the pylorus

Following the observation that liquid mercury will carry the Miller Abbott tube down the gastro-intestinal tract even if the balloon is not inflated with air Harris devised a single lumen tube the balloon of which contains four to six c.c. of mercury The principle upon which Harris bases his tube is, "that of a weighted bag carrying the tube down into the small bowel by force of gravity, in contrast to the principle of peristaltic activity grasping the inflated bag of the Miller Abbott tube [199] The construction of this tube head is almost identical with those of the Miller Abbott and Johnston tubes in the sense that in all these tubes the balloon is placed along the shaft of the tube The result of this is that only the weight of mercury is utilized because of the restraining influence of the tube shaft through the balloon Here is a tube whose original design was created for air filled balloon being used to carry mercury In the technic of use of this tube, after the tube has entered the stomach and the stomach has been completely emptied *the patient is propped upon on his* right side in the semi Fowler position in the exact manner as described in the original technic of Miller and Abbott. If the patient is not too sick he is permitted to stand up and even walk around for from five to ten minutes The tube is then passed one inch every ten minutes

The Cantor[200] tube was constructed specifically to utilize all the physical properties of mercury i e weight, mobility cohesive power and extreme lability To utilize all these properties to *the utmost the balloon* was made loose and attached to the very

tip of the tube so that there would be no limitation to the 'free flow' of the mercury

Since this tube was designed specifically for the treatment of intestinal distention it was simplified to the greatest possible degree The technic of use of this tube in addition, has been simplified as to make it almost fool proof and it does not require the use of fluoroscopy to insure successful passage The principle that must be borne in mind to secure successful intubation is To utilize the free flow of mercury in a loose sac at the tip of the balloon always move the patient so that the anatomical part to which we desire the tube to go will be down-hill This can be done in the stomach and duodenum but in the small bowel where twenty four feet of bowel is suspended by a six inch mesentery and where the loops of bowel lie in every conceivable plane motion of the patient is utilized for successful intubation The use of this tube has been simplified down to the following directions

A *Preparation of the tube*

1 Using a ten c c syringe and an eighteen gauge needle inject five c c of mercury into the balloon through the last hole
2 Aspirate all the air left in the balloon with the ten c.c syringe immediately after injecting the mercury
3 Insert the stylet of a 21 or 22 gauge needle through the last hole and pass it into the balloon Tie off the end of the tube as follows and then remove the stylet Place a strong tie of twenty five pound pull fishline or braided silk over the point at which the bag it cemented to the end of the tube as noted in Fig 50 The tie should be wound around the tube twice and should be tied with a square knot If this tie is applied very tightly it will be found that when the stylet is removed that a minute opening or safety valve is left in the tube for gases to escape The size of the hole is so small however that the mercury cannot escape To accomplish this, only the stylet of a 21 or 22 gauge needle can be used and the tie must be tied over this stylet as tightly as possible
4 Dip the end of the tube in mineral oil
5 The tube is now ready to be inserted into the patient's nose

B *Preparation of the patient and passage of the tube*

1 Give the patient a hypodermic of morphine sulphate gr ⅙ and atropine sulphate gr 1/100 to allay nervousness and neutralize to some extent vagal effect upon stomach sphincters.

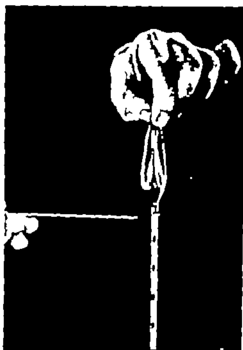


Figure 50. Place tie on the end of the tube at the point at which the balloon is attached Use two loops and tie very tightly over 21 or 22 gauge stylet to trap mercury in the balloon. By so doing balloon cannot tear off with mercury in it and balloon is not weakened at its neck permitting air to enter

2 Examine the nose to determine if there is any local pathology Spray or swab the side of the nose through which the tube is to pass with ephedrine in oil 2% and pontocaine 2%

3 Now, with the patient sitting up or lying on his back, and with the head hyper-extended so that the nasal passage now runs downhill the balloon is inserted into the nasal passage To do this any one of three methods may be successfully employed. The simplest is to grasp the balloon between the thumb and index finger thus permitting the mercury to run to the neck of the balloon The balloon between the thumb and index finger being empty is now folded up to form an empty spur of balloon, this empty spur is inserted in the downhill passage of the nose as far as it will go Now releasing the thumb and index finger permits the mercury to run into the empty spur dragging the tube into the naso-pharynx A second method is to grasp the balloon between the thumb and index finger



Figure 51 Simplest method of introducing the Cantor tube into the nose is to introduce an empty spur of balloon into nose with the head hyper extended. The mercury in the balloon is kept from running into the spur by holding the balloon between thumb and index finger as shown.



Figure 52 An alternate method is to introduce the spur of balloon into the nose by pushing it backward using a cotton tipped applicator Note the head of the patient being hyper-extended



Figure 53 A third method which is very useful when the patient has a perforation of the nasal septum is to introduce the spur of empty balloon by using a bayonet forcep. Note the downward direction of the external nares. Mercury may enter the spur by this method but it does not create any difficulty in intubation



Figure 54



Figure 55

Figure 54 Lateral roentgenogram after the tube head has entered the nose. Note how the mercury has adapted itself to the nasal passage.

Figure 55 Tube-head in the naso-pharynx and beginning the descent into the oro-pharynx and esophagus as seen by x ray

as noted above insert the empty spur in the nose, and then push it back into the nasopharynx with a cotton tipped applicator. A third method is of value when there is a perforated septum. In this method the empty spur is inserted into the nose using a bayonet forcep. Once the balloon is well into the nose the mercury will drag the balloon into the nasopharynx if the head is hyperextended.

Remember that the mercury has been sealed into the balloon before it is inserted into the nose. No mercury is added and nothing is done to tube after inserting.

4. When the balloon containing the mercury has dropped into the nasopharynx the patient is permitted to sit up



Figure 56



Figure 57

Figure 56. Note the downward pull of the tube head containing the mercury passing through the oro-pharynx and entering the esophagus. Again notice the adaptability of the soft compressible balloon of the Cantor tube containing the mercury to the space in the esophagus. The fact that the balloon lies free at the very tip of the tube permits it to adapt itself to any space of even the smallest caliber.

Figure 57. The tube head has passed through the esophagus and dropped into the stomach. Here we see the tube in the esophagus and the holes can be noted at the external nares. The tube (Cantor) must be passed until the marking "S" appears at the nose. When this occurs, the holes seen in this figure at the external nares will now fall in the lower esophagus and stomach.



Figure 58



Figure 59

Figure 58. The patient as in Figure 59 when turned on his back flat on the table. Note that the tube head comes to lie in the left para vertebral gutter Figure 60. The patient as in Figure 59 when permitted to stand up. Note the marked change in position of the tube head when compared with Figures 58 and 59 Note how tube head changes with every change in position of patient due to the free flow of the mercury Figure 61 Stomach five years following Polya type of partial gastrectomy Notice position of gastric stoma in the floor of the stomach (along the greater curvature) Turning this patient on his face and raising the foot of his bed would result in the tube head passing upward into the proximal loop. This would carry tube head into a cul-de-sac.

Figure 59 With the letter P at the nose and the patient turned on his right side face downward and the foot of the bed elevated twelve to fifteen inches, the tube head immediately comes to lie at the pylorus as noted in this roentgenogram.

and take one drink of water The pharyngeal constrictors grasp the bolus of balloon and the water with the result that the highly motile balloon literally shoots down the esophagus and into the stomach. The gastric contents begins to run freely from the end of the tube. At this point the letter S' will be noted on the tube presenting at the external nares This is sufficient tubing to carry to the fundus of the stomach but not enough to pass through the pylorus An additional piece of tubing is passed until the letter P presents at the nose During this time suc



Figure 60

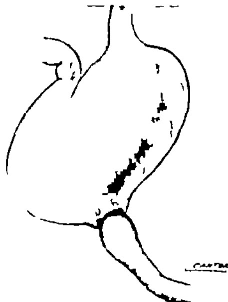


Figure 61

tion has been connected so that decompression is going on Now the patient is maneuvered so the tube head will pass through the pylorus

5 Turn the patient on his right side and inclined face down and also raise the foot of the bed twelve inches With the letter 'P' at the nose there will be sufficient tubing to carry the tube head to the apex of the stomach funnel (the pylorus) when the patient assumes this position Remember that the fundus of the stomach lies on a plane posterior to the antrum and pylorus when the patient lies flat on his back If the patient is left on his back then invariably the free flowing mercury would drop into this pouch of stomach in the left para vertebral gutter and remain there Turning the patient on his right side is not enough to secure successful passage because in the fish hook type of stomach or ptotic stomach with a low greater curvature there is often a sharp angle between the fundus and antrum and pylorus In addition the first limb of the duodenum runs upward To utilize these facts in order that the first limb of the duodenum may pass downhill we turn the patient on his right side inclined



Figure 65



Figure 66

Figure 65 Same patient at 1·00 p.m. Note that the tube head is now at the duodeno-jejunal flexure. The Cantor tube in this case passed through the pylorus rapidly We generally allow two hours for each change of position and take our first roentgenogram at the end of six hours.

Figure 66 Tube (Cantor) passed into the stomach at 11 15 Patient flat on his back Note position of tube head toward left para vertebral gutter

There will now be sufficient tubing to carry the tube head to the duodeno-jejunal junction The reason for this is the downhill direction of the second part of the duodenum when the patient sits up Thus always permitting the loosely confined mercury to run downhill

7 At the end of two hours in the above position, the back rest is lowered and the patient is turned on his left side He is kept in this position for two hours. At this point an additional four inches of tubing is passed. There will now be sufficient tubing to carry the tube head into the jejunum The reason the patient is turned on his left side is the anatomical fact that the third portion of the duodenum runs from right to left With the patient on his left side the duodeno-jejunal junction is now downhill permitting the tube head to run toward it.

8 After two hours in the above position, a check up x ray is taken in the patient s bed to note the position of the

tube When a tube is inserted preparatory to an elective operation such as a resection of the right colon the first x ray is taken at twenty four hours

9 From this point on the patient is encouraged to move about freely and even to ambulate or sit in a chair if at all possible With motion of the patient there is movement of the loosely confined mercury in the tube head and as a result descent of the tube All the above maneuvers are predicated upon the premise that there is little or no peristaltic activity and that the stomach is in a poor state of tonus We expect no help from the patient in such cases and rely solely upon the free flow of the mercury in the loose balloon to successfully intubate the patient If the stomach is in tone and there is peristaltic activity, such as in intubating for an elective operation, in a patient that is not distended the tube head will rapidly pass through the pylorus and down the gastro-intestinal tract without doing any special maneuvers In such cases, unless watched, the tube head may present itself at the anus in forty-eight hours or less The intervals of two hours in each position as noted above, is an arbitrary period of time that we set for the sake of uniformity and because we do not use the fluoroscope One x ray at six or twenty four hours is all that is required by using this simplified procedure and the sick patients are spared the necessity of repeated trips to fluoroscopy Actually, we have found in a great number of cases that were observed that at the end of two hours, the tube head came to lie at the duodeno-jejunal junction and many showed at the end of six hours that the tube head was well along the jejunum Regardless of this, we utilize two hours in each position for the sake of uniformity and to make the procedure as simple as possible

It may rarely be found that the patient will be obese with a tremendously distended abdomen and a poor myocardium who may become cyanotic when he is put in the position on his right side inclined toward his face and the foot of the bed elevated In such cases, putting the patient in a chair will usually result in a successful passage We



Figure 67



Figure 68

Figure 67 Same patient as Figure 66. Patient in standing position film taken three minutes later at 11 18 Note the marked change in the position of tube head due to change of position of patient.

Figure 68 Same patient as Figures 66 and 67 Note position of tube head two hours after intubation. Film taken at 1:00 p.m. Tube head is now at duodeno-jejunal flexure.

had one such case and were able to successfully intubate him

The tube must not be fastened to the side of the patient s face Permitting it to lie free, insures its passage downward unaided when peristaltic activity is re-established and the thrashing about in bed of the patient and the involuntary swallowing of saliva often results in a foot or more of tube being passed unaided during sleep

In feeding the tube into the patient we do not push the tube in. We rely upon the downward pull of the pharyngeal contrictors acting upon the bolus of water and tube to pass the tube This is a physiological method of passing a tube and not forcibly pushing it against muscle contraction. The tube is held loosely and everytime the patient swallows a bolus of water the hand holding the

tube is brought gently toward the face of the patient It will be noted that the tube moves down readily with each act of deglutition

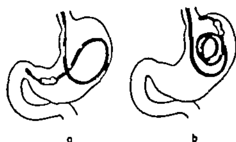


Figure 69 Result of passing too much tubing into the stomach and attempting to rush the passage of the double lumen tube. Coiling in the stomach hinders downward movement of the tube and favors knot formation. (*From* Johnston, C. G Nelson's Loose Leaf Surgery)

No more than four inches of tubing must be passed at one time. To do so invites coiling We advise passing two inches of tubing every two hours If this is done two feet of tubing can be passed in twenty four hours This does not mean two feet of bowel for it can easily be demonstrated that twenty four feet of small bowel will string along three to four feet of tubing When the five foot marking on the tube presents at the nose, the tube will generally be found in the lower ileum. When the six foot mark presents at the nose, the tube head will often be in the colon.



Figure 70 Effect of passing too much tubing of the Cantor tube into the stomach. If left alone for several hours and no more tubing passed this tube will straighten itself out. This, however is an error in technic of intubation.

We permit the tube to pass down as far as it will go in any case of intestinal distention In paralytic ileus, it will be found that more time is required to get the tube head down into the ileum The upper jejunum, stomach and duodenum are decompressed in such cases within the first twenty four hours

When the head of the intestinal decompression tube has passed into the ileum or even into the colon and the specific disease of the patient requires the use of the tube for more than five days, special attention must be given to the stomach In cases of this type secondary dilatation of the stomach due to the presence of the foreign body (tube) within it for this period of time is not unusual As a result of this, gastric dilatation, epigastric distress and vomiting are the usual findings despite the presence of a long tube far down the gastro-intestinal tract. In extreme cases the gastric dilatation may be so marked as to produce respiratory embarrassment. In controlling this complication the procedure employed varies with the type of long tube being used. If the Miller Abbott tube is being used, then to decompress the stomach a Levin tube must be passed through the other nostril into the stomach and suction applied This necessitates the use of two suction units running at the same time. Using two tubes effectively precludes nasal breathing with the result that oral breathing must be used This is not only unphysiological but uncomfortable for the patient In using a single lumen intestinal decompression tube such as the Cantor tube, all that is required to prevent gastric dilatation is to cut four more holes in the tube and permit the tube to be passed twelve more inches This will carry the holes into the stomach Now with the holes in the stomach gastric and intestinal decompression is carried on simultaneously There is no loss of suction by putting these holes proximal to those in the small bowel The great increase in intra-gastric pressure forces the gastric contents into the tube so that very little negative pressure is lost. In the small bowel also in addition to the negative pressure sucking the intestinal contents into the tube we have a positive intra intestinal pressure forcing the intestinal contents into the holes in the tube The tube is so strongly radio-opaque that the holes visualize well A flat plate of the abdomen will permit the roentgenologist to tell the surgeon exactly where the holes in the tube lie along the gastro-intestinal tract

In the event that the tube head presents itself at the anus then the tube is removed by pulling it out through the anus since



Figure 71



Figure 72

Figure 71 Patient C. P., Male White Age 60 Diagnosis Carcinoma of the caecum. Cantor tube passed two days before operation. Note position of tube At operation, head of tube found at the ileo-caecal valve. After resecting this bowel be sure to pull tube head back to jejunum to prevent it from going through the anastomotic stoma.

Figure 72. Patient G E., Male White Age 52. Diagnosis Diverticulitis of the sigmoid with bowel obstruction. Note position of the tube head in the sigmoid colon down to the point of obstruction.

the need for an intestinal decompression tube would no longer exist

In any case in which the intestinal decompression tube is used preliminary to doing a resection of the right colon the patients are permitted to be ambulatory They are given a regular diet if not obstructed The first film in a case of this type is taken twenty four hours after intubation When the film shows the tube head in the terminal ileum then the tube is fastened to the face of the patient to prevent it going any *further* *In cases of this type* we want our tube to remain in the terminal ileum and go no further

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CHAPTER VIII

ROLE OF MERCURY IN INTESTINAL DECOMPRESSION TUBES

THE use of mercury in intestinal obstruction is not new Over one hundred and fifty years ago mercury was used by mouth in its free form in the treatment of bowel obstruction. In the Index of the Surgeon General from the years 1780 to 1850 no less than fifty articles[201, 202, 203, 204] can be found describing the action and use of metallic mercury by mouth in the treatment of bowel obstruction Although this method of treatment fell into disrepute for obvious reasons, certain fundamental points were learned by these surgeons and it called attention to mercury in cases of bowel obstruction The early work with mercury proved that liquid mercury was innocuous in the gastro-intestinal tract and it was further emphasized that it was not the weight of the mercury that was the desirable property but rather its fluidity, its lability and the quick silver qualities of the mercury that were the most desirable properties Dujardin-Beaumetz (1886)[205] discarded the use of mercury because their experiments had shown that it did not descend in bulk but rather penetrated slowly globule after globule.

The first use of mercury in a gastro-duodenal tube appeared in 1928 with the publication by Wilkins[206] describing a mercury weighted gastro-duodenal tube This tube was three sixteenths of an inch in diameter and the mercury was packed solidly into the head end of the tube An examination of this tube readily discloses the obvious fact that the only physical property of mercury utilized here was its weight. Because the mercury was closely confined in so small a space there was no opportunity for the lability and cohesive power of the mercury to be utilized. The very title of the paper indicates quite clearly that the weight of the mercury was the prime object.

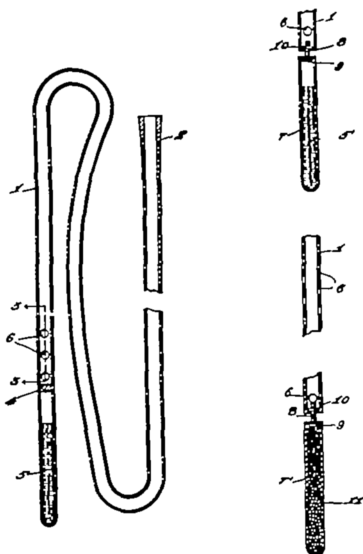


Figure 73 Wilkins Tube. This is a four foot long gastroduodenal tube. It is three sixteenths inch in luminal diameter Note that the mercury is packed tightly into the end of the tube This means utilization of mercury as weight only

The role of mercury in the balloon of the long intestina compression tube appears to be misunderstood Most surg are under the *erroneous belief that it is the weight of the me* that carries the intestinal decompression tube down the ga *intestinal tract. The effect of gravity upon the weighted hea* the tube is thought to constitute the propulsive mechanism effect is utilized by Harris in his single lumen tube and in work of Harris and Sivertsen in placing mercury in the bal of the Miller Abbott or Johnston tubes

If it were merely weight that was desired in the head of an intestinal decompression tube, there are other elements are heavier than mercury and hence more desirable from point of view An examination of the table of elements and t atomic weights discloses the fact that there are eight elem whose atomic weights exceeds that of mercury with an ato weight of 200 61 Some of these elements such as radium (ato weight 225 95) radon (atomic weight 222) and thorium (ato weight 232 15) cannot be used because of their physical prop of radio-activity This property makes their use to weight head of an intestinal decompression tube impossible Thall (atomic weight 204 39) cannot be used because of its toxicit the event the balloon would break freeing the thallium into gastro-intestinal tract. Bismuth (atomic weight 209) is m too brittle as a metal and not readily available. It has no flui or cohesive power that would make its use in the head of a t desirable The only remaining element heavier than mercur lead (atomic weight 207 20) If it is weight alone that is desi why not use lead which is heavier than mercury? In additior being heavy it is relatively non-toxic in the gastro-intestinal tr because it would be excreted before much absorption could occ It should be quite apparent that although lead is heavier t mercury its other physical properties of *being a solid mass* a inert would not fit it well for use in an intestinal decompress tube which is expected to pass through sinuous passageways w sphincters as is found in the gastro-intestinal tract. Mercu on the other hand because of its fluidity and cohesive power eminently suitable for use in the balloon of an intestinal dec

pression tube because it literally flows downward through narrowed portions of the bowel and passes sphincters easily

Since mercury is to be used in the head end of the intestinal decompression tube such tubes must be constructed to utilize the physical properties of mercury to the utmost and not merely its weight Metallic mercury is liquid even at the lowest temperatures It is a coherent mobile liquid, which does not wet glass or objects placed in it It remains liquid under a wide range of temperatures from — 39 to + 360 It remains unchanged in dry air, oxygen, nitrous oxide and carbon dioxide but in damp air it slowly becomes coated with a film of mercurous oxide which is not particularly important when used in a tube head Mercury remains unattacked by dilute sulfuric acid and hydrochloric acid when concentrated has only slight action upon the mercury This property, its complete insolubility in acids, makes mercury an excellent element for use in the head end of the tube because it is completely non toxic in its metallic form in the gastro-intestinal tract. Reviewing the physical properties of mercury, we find its lability, marked motility and cohesive power as being the most desirable features for its use in the head of an intestinal decompression tube, and its non toxicity and weight as being of lesser importance

To utilize all these physical properties of mercury to their best advantage, it is necessary that the mercury be placed in a bag that will give it (mercury) a free range of motion We must not limit the free play of the mercury in the balloon if we are to utilize these most desirable properties For this reason we have designed this simplified intestinal tube which permits the maximum utilization of all the physical properties of metallic mercury and not merely the effect of gravity upon its weighted mass. It should be noted that the ample balloon at the tip of the tube permits a 'free flow' of the metallic mercury With this mercury trapped in the balloon, which permits it to flow freely, it is only necessary to place the patient into position so that the mercury will always have an opportunity to flow downhill or from side to-side in order to secure rapid passage of the tube down the gastro intestinal tract. It must be remembered that

mercury will not run uphill, unless forced upward by peristaltic activity

The amount of mercury to be placed in the balloon of the simplified intestinal decompression tube (Cantor) varies with the size and age of the patient being intubated as well as the physical condition of the patient. In children we have found that two to four cubic centimeters of mercury is sufficient. In younger children, we generally use only two cubic centimeters of mercury The larger amount being used in older children or those that are apprehensive In this latter type of case the larger amount of mercury will tend to overcome sphincteric spasm

In adults the amount of mercury ranges from five to ten cubic centimeters In the vast majority of cases, five c.c of mercury is adequate In patients suffering from atonic or paralytic ileus we have noted on numerous occasions that five c c. was not sufficient to insure successful intubation, but that nine c c. would invariably result in a successful intubation *Fig 73a* and *73b* furnish an excellent example of this. This patient was a seventy six year old woman with marked atony of the bowel and carcinoma of the sigmoid colon In intubating this patient, 5 c.c. of mercury was *used in the balloon of the Cantor tube We were unable to success*fully intubate her with this amount of mercury The tube was then removed and nine c.c. of mercury placed in the balloon In twenty four hours the tube was found to be well down the ileum as seen by roentgen ray (See Fig 73a) Two days later the tube head was found in the ascending colon (see Fig 73b) During the period of intubation with the increased amount of mercury the patient was ambulated at frequent intervals We have had similar experiences on many occasions Peritonitis, which is one of the most common etiological factors in the production of ileus demanding intubation is no contra indication to ambulation By ambulation and increasing the amount of mercury used to seven or nine c c a very great increase in successful intubations will be obtained in this type of case

Nervous and apprehensive patients in whom the intubator can expect sphincteric spasm may be more readily intubated using a larger amount of mercury—7 to 9 c c.

Figures 73a and 73b demonstrate rather well that with am

bulation even nine c c of mercury in the balloon of an intestinal tube will permit that decompression tube to progress rapidly down the gastro-intestinal tract In using an amount of mercury so large the patient must be ambulated because the weight of the mercury is such that lying quietly in bed the depressed intestinal motility may not be strong enough to carry the tube downward





Figure 73a Figure 73b

Figure 73a. Note the presence of the strongly radio-opaque intestinal tube far *down the intestinal tract. This was a twenty four hour film.*

Figure 73b. Note that on the third day after intubation that the tube head is found in the ascending colon.

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CHAPTER IX

DISORDERS OF THE SMALL BOWEL REQUIRING INTUBATION

FOR purposes of intubation disorders of the small bowel may be divided up into four main groups These groups are (1) All cases of ileus due to atony of the bowel, or adynamic and dynamic All cases in which the distention is not in any way due to mechanical obstruction (2) All cases of intestinal distention as a result of ileus caused by inflammatory lesions In this group would fall all cases of ileus due to general peritonitis local peritonitis, plastic exudate inflammatory masses and any inflammatory process capable of causing ileus (3) All cases of ileus due to mechanical lesions These may vary from mesenteric thrombosis to carcinoma of the recto-sigmoid (4) Patients subjected to elective operations or who would ordinarily have an enterostomy preparatory to anastomosis of the bowel or resection

ATONIC ILEUS GROUP

This group of cases constitutes one of the largest that the surgeon is called upon to intubate and a group in which intubation alone may be used It is in this group of cases that intubation may be a life saving measure without the necessity for surgical intervention In the early part of this century the treatment of this group of cases was enterostomy or jejunostomy Victor Bonney[107] of England in his writings upon Paralytic Obstruction of the Intestine, with Special Reference to its Treatment by Jejunostomy noted that in many of the cases in this group that had been subjected to enterostomy that there was little escape of gas and that vomiting continued and distention remained. He therefore concluded that in atonic ileus it was useless to open the bowel and that jejunostomy was the treatment of choice By intubation what we get in fact is non-surgical jejunostomy or

enterostomy without the dangers associated with the surgical approach It is a well established fact at present and known to all surgeons that one cannot decompress the gastro-intestinal tract in paralytic ileus by enterostomy The only result of such procedures is that one or two loops of bowel are drained and the remainder of the intestinal tract remains atonic and distended with gas and fluid

It was in this type of case that the earlier workers on intestinal decompression as Ward Westerman, Ochsner and Wangensteen began the pioneer work of the suction treatment as applied to an indwelling gastro-duodenal tube. The results in the early type of post-operative distention in which the distending element was chiefly gas and the atony was due to a motor disturbance of the gastro-intestinal tract as a result of the operative procedure were truly brilliant The results in the treatment of paralytic ileus associated with peritonitis were also excellent. The reports of these early workers called attention of the world at large that here at last we had a method of treating these complications with no risk and much assurance of successful culmination as far as the distention was concerned. Long before the advent of the sulphonamides and penicillin many lives were saved in just this group of cases by intestinal decompression via suction applied to a gastro-duodenal tube and relying upon the protective forces of the patient to wall off the infection or absorb it. Here then was the first step in the right direction away from the surgical approach (enterostomy) with a high mortality due to failure to decompress toward gastro-duodenal suction drainage with a much lower mortality due to greatly improved decompression

There is a wide latitude in the degree and extent of the atonic process involving the gastro-intestinal tract from the mild post operative distention to the severe types of paralytic ileus found with retro-peritoneal lesions In addition, the type of patient suffering from the atonic bowel is an important consideration in the proper selection of the type of tube to be used It should be quite obvious that a young and otherwise healthy, adult suffering from post-operative intestinal distention due to a temporary atony of the bowel constitutes a far different problem from the elderly malnourished man suffering from a perinephritic abscess

with a resultant paralytic ileus For this reason an attempt will be made to describe some of the conditions that the intubator may meet in order that he may be able to rationalize for himself just when a specific tube should be used and just how much will be accomplished with the tube in question

Post-operative intestinal distention constitutes a large group of cases that the intubator may be called upon to see It is essential that he know before inserting a tube just what the etiology of this distention may be because the proper selection of his tube depends upon it. In those cases of post-operative distention due to an atony of the bowel from the surgical trauma and unaccompanied by infection within the peritoneal cavity, one can be fairly certain that the distending element is gas Most of it being swallowed air and that the amount of gas in the gastro-intestinal tract is being augmented by the continued post-operative swallowing by the patient This type of patient does not require the use of a long intestinal decompression tube A Levin tube inserted into the stomach with some type of continuous suction applied will quickly result in intestinal decompression In some hospitals this type of case is treated by drugs as prostigmine and withholding everything by mouth for several days Equally good results may be obtained by either method The recent work of Leithauser[303] on early ambulation has shown that the post-operative distention of this type formerly so troublesome is found much less often in patients treated by early ambulation than in those at bed-rest. In addition, it has been shown that these milder types of intestinal distention rapidly clear up with the patient ambulatory due to the improvement in the physiological processes of the body which were temporarily altered by operation

On the other hand if the post-operative distention is not due to the atony resulting from the surgical trauma but rather to a beginning peritonitis either local or diffuse, then the surgeon had better be prepared to decompress a paralyzed bowel filled not only with gas but also with fluid. In this type of case, a long tube is the instrument of choice for only by using a tube of this type which passes far down the gastro-intestinal tract can one adequately drain the lower reaches of the ileum We must note at this point and repeat throughout this book that the intestinal

decompression tube is merely an instrument and must be used as such The thinking must be done by the surgeon in charge He must select his tube on the basis of a proper diagnosis and not expect more from any tube than it is capable of delivering Paine has demonstrated that while suction applied to a duodenal tube in the stomach was highly efficient in decompressing the stomach alone, it was necessary to insert the tube through the pylorus into the duodenum to obtain satisfactory decompression of the upper small intestine The explanation for the decompression obtained by many patients intubated with a Levin tube, which so often remains in the stomach, is to be found in the rhythmic contraction and relaxation of the pylorus During the period of relaxation gas can be drawn up into the stomach and hence sucked out. In order to suck out intestinal liquid matter, it would necessarily have to be forced upward into the stomach by a reversal of the intestinal stream or by an atony of the pyloric sphincter

One must select a tube then on the basis of whether he is content to decompress the stomach and duodenum or whether he wishes to decompress the entire small bowel. In the latter event or in the event that the surgeon wishes to be prepared for all eventualities it is far better to insert a long intestinal decompression tube By using a long tube, if gastric decompression alone is desired it may be obtained by keeping the tube in the stomach This can easily be done by fastening the tube to the nose after it has entered the stomach If it should become apparent that the case is not one of post-operative atonic distention but rather a case of local or diffuse peritonitis with distention one can readily permit the tube to pass on downward into the small bowel giving adequate decompression

Retro-peritoneal lesions notoriously are capable of producing paralytic ileus In many of these cases the intestinal distention is severe and must be adequately treated if one is to avoid the deleterious effects associated with it. The treatment of the primary disease, however must go on quite independently All these cases of paralytic ileus can be adequately treated by intestinal intubation alone, and often will make all the difference between the life or death of the patient. Some of the most common lesions asso-

ciated with paralytic ileus found in this group are Aneurysm of the abdominal aorta with leak of blood into retro-peritoneal tissues These cases are occasionally seen and the usual complaint is pain in the abdomen with tremendous distention One of our earliest cases was admitted with a tremendous distention and pain in the abdomen A diagnosis of abdominal aortic aneurysm was not difficult but the intestinal distention was very troublesome Continuous vomiting was rapidly deteriorating the patient Intestinal intubation with the simplified long tube resulted in a rapid resolution of the intestinal distention Large amounts of liquid material was aspirated from the gastro-intestinal tract On some days as much as four thousand c c. being obtained Intestinal intubation in this type of case is merely palliative as the primary lesion was one which would not lend itself to surgical correction

Pyelo-nephritis peri nephritis, ureteral calculi and many other



Figure 74



Figure 75

Figure 74 Patient I A., Male, White, Age 70 Diagnosis Paralytic ileus with pyelo-nephritis. Note distention of the gastro-intestinal tract.

Figure 75 Patient I A., Male White, Age 70 Same patient as in Figure 74 Note the position of tube head after intubation. A small amount of dilute barium given to rule out an obstructive lesion on a mechanical basis.

K U B tract lesions are quite apt to result in intestinal distention due to paralytic ileus On occasion following cystoscopy for diagnosis a severe type of intestinal distention may supervene. The distention which in this type of case is purely the result of paralytic ileus from reflex irritation will completely resolve when the causative factor is adequately controlled Intestinal intubation



Figure 76



Figure 77

Figure 76. Patient M P Female White, Age 50. Diagnosis Paralytic ileus—post-operative Note marked distention of gastro-intestinal tract.

Figure 77 Patient M P., Female, White, Age 50. Same patient as in Figure 76. Intestinal tube two hours after intubation. Note decrease in intestinal distention.

with the long tube by controlling the distention gives the urologist or surgeon time to take care of the primary disease by keeping that patient deflated. In so doing many lives have been saved, particularly in the older age group that might otherwise have been lost as a result of the uncontrolled paralytic ileus

Retro-peritoneal tumors not infrequently cause the development of a paralytic ileus both pre-operatively and especially post operatively In this type of case, the use of a long intestinal decompression tube pre-operatively will serve a dual function It will not only deco the gastro-intestinal tract so that the

patient will be in much better condition for operation but also by the plicating effect of the small bowel on the tube it will be found that the entire small bowel will be strung along four feet of tube In this way the operative field is made much better particularly if the surgical approach is trans abdominal Then leaving the tube in situ it prevents the post-operative distention so often found in surgery of this type

The gastro-intestinal atony so often found in the aged precipitated by intercurrent infection or trauma not infrequently results in a distention so severe as to be of great concern In these elderly patients in whom both the gastro-intestinal as well as the skeletal musculature is atonic the passage of a long tube far down the gastro-intestinal tract requires considerable tact, patience and judgment on the part of the intubator Since there is little or no peristaltic activity and the stomach is usually atonic, we must depend for successful intubation upon the technic of intubation itself and must select a tube that does not require peristaltic activity to carry it downward Since the Miller Abbott and Johnston tubes depend upon the action of peristalsis upon an inflated balloon for its downward passage, it should be quite evident that they are not well suited for this type of case The only tube that we have found that will invariably pass through the pylorus in these cases and does not depend solely upon peristaltic activity is the simplified intestinal decompression tube (Cantor) This tube is particularly well suited to this type of case because motion of these elderly patients and even ambulation is very desirable. Strict bed rest for such patients invites hypostatic pneumonia Since the simplified intestinal decompression tube depends solely upon a free flow of mercury in a loose sac at the end of the tube quick changes in position results in a movement of the tube head In some of the larger patients of this type an increase in the amount of mercury in the sac to seven c.c very often will result in a speedy passage through the pylorus and duodenum

It should be emphasized that paralytic ileus in an individual may be complicated by some degree of inflammatory bowel obstruction or by an abscess somewhere in the abdomen While the treatment of the paralytic ileus is by intubation alone the treatment of the complicating factor may require surgical intervention Because the intestinal distention has been brought com

pletely under control should not lull the surgeon into a false sense of security Before the long intestinal decompression tube is removed in such cases it should be established beyond any reasonable question of doubt that the case was really one of paralytic ileus and that the interference with the intestinal stream has been completely removed This can be done in one of two ways A small amount of barium may be given through the tube or by mouth and its downward course checked by x ray If the barium is readily evacuated and if the patient passes gas and feces per rectum, it is safe to remove the tube. In the event that the barium does not pass through or stops at a point of partial blockage, it can be readily aspirated without any danger to the patient. The simplified intestinal decompression tube is admirably suitable for this type of work because it is 18 Fr and the holes for aspiration are of such size that they will not become plugged The Miller Abbott tube, although often used in this way may become plugged by the barium particularly if not made very dilute A second method of determining when to remove the tube in such cases is the clinical method By this method the tube is clamped off for two hours three times a day for one day then the next day for three hours three times a day and on the third day for twenty four hours. If the patient does not become distended and passes gas and stool per rectum it is considered safe to remove the intestinal decompression tube

INFLAMMATORY DISTENTION GROUP

This group of cases constitutes by far the largest group of cases to be intubated as well as the group in which the use of the long intestinal tube may be said to give truly brilliant results In this group of cases, however there are some that require surgical intervention in addition to the use of the tube as well as strict attention to the water balance and electrolyte equilibrium of the patient The recent introduction of the sulphonamide drugs and the use of penicillin has resulted in a remarkable reduction in mortality for this type of case from twenty per cent to less than five per cent

We include in this group any case of ileus in which the causative factor is an inflammatory process within the abdominal cavity This may be the result of a generalized peritonitis, local peri-

tonitis, abscess anywhere within the peritoneal cavity as pelvic abscess, retro-caecal abscess, inflammatory adhesions, or plastic exudate In this group of cases, intestinal intubation for the treatment of ileus is the greatest single measure we have Long before the introduction of sulphonamides and penicillin numerous lives were saved by intestinal decompression and intravenous fluids



Figure 78



Figure 79

Figure 78 Patient R. S., White Female Age 54 Diagnosis Peritonitis with paralytic ileus. Cantor tube well down the gastro-intestinal tract in forty eight hours.

Figure 79 Patient G R., White Male Age 49 Diagnosis Peritonitis with paralytic ileus. Note tremendous intestinal distention.

Since the introduction of sulphonamides and penicillin the mortality rate in such cases has dropped to a very low figure. In cases of diffuse peritonitis intestinal intubation alone is sufficient to combat intestinal distention Whether such intubation is used pre-operative as in the treatment of diffuse peritonitis due to late ruptured appendicitis by the Ochsner technic or post-operatively after appendectomy the intestinal decompression obtained is one of the greatest single factors in our therapeutic armamentarium Intestinal distention was formerly a serious problem in



Figure 80

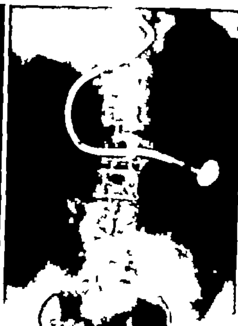


Figure 81

Figure 80. Patient G R. White, Male Age 49 Same patient as in Figure 79 Film taken approximately ten hours after intubation. Note visualization of holes in the Cantor tube

Figure 81 Patient I M., White Male Age 55 Diagnosis Peritonitis with paralytic ileus. Cantor tube six hours after intubation.

the treatment of peritonitis By introducing a long tube far down the intestinal tract, we no longer have to contend with this factor and can direct our attention to restoring the normal physiology of the blood

Local peritonitis such as is found in pelvic peritonitis with tubo-ovarian abscess constitutes an individual problem in intubation In cases of this type the ileus may be of two types First as a result of the paralytic ileus resulting from the peritonitis with reflex nervous involvement and secondly there is often a knuckle of bowel adherent to the inflammatory pelvic mass producing edema of the bowel wall and obstruction Intestinal intubation in this type of case may be the sole method of treatment of the intestinal distention or patients may require later surgical intervention When the long intestinal decompression tube is passed well down the ileum and the abdomen is decompressed an opportunity is



Figure 82



Figure 83

Figure 82. Patient H G., White Female Age 36. Diagnosis Intestinal obstruction—pelvic abscess. Note the degree of intestinal distention.

Figure 83 Patient H G., White, Female Age 36 Diagnosis Tubo-ovarian abscess. Bowel obstruction. Position of tube head six hours after intubation.

offered for the bowel wall edema to subside and release the obstructed bowel If the ileus is solely due to paralytic ileus from pelvic peritonitis generally by the fifth day gas is passing freely per rectum and the patient may have a bowel movement. In such an event, the tube is clamped for two hours three times a day If by so doing the distention returns then the suction is re applied to the long intestinal tube and the surgeon can be reasonably certain that a knuckle of bowel is adherent to the pelvic inflammatory mass and may require surgery An effort should be made however to permit the inflammatory mass to subside in order to see whether the obstruction will thereby be released A period of waiting of two weeks is not too long provided the temperature is coming down and the w b c is returning to normal and if the intestinal decompression tube adequately keeps the gastro-intestinal tract empty During this period of time intravenous alimentation and high caloric liquid diet may be given

orally With the head of the tube down in the ileum, some of the orally ingested material will be absorbed before it is suctioned out. When the inflammatory mass has subsided as shown by pelvic examination or after surgical drainage, then one can readily determine when the tube is to be removed. If the patient is passing gas per rectum and has had one or more bowel movements we can consider removal of the tube. Clamping the tube for two hours three times a day should not result in a return of the distention. If it does not the tube is clamped all day If the distention does not return and the patient is passing gas per rectum the tube is removed In the event that clamping the tube results in a return of the distention, then the abdomen is decompressed and surgery is definitely indicated to free the bowel from the subsided inflammatory area Generally in such cases no definite adhesive bands are found as the bowel is adherent by firm granulation tissue to the inflammatory mass. Separation of the bowel usually results in a loss of serosa which requires peritonealization. Rarely is resection required in such cases and strangulation is most unusual The antimesenteric surface of the bowel is the usual site of adherence so that circulatory impairment of the bowel wall is the exception



Figure 84 Patient H G., White, Female, Age 36. Diagnosis Intestinal obstruction—pelvic abscess. Note marked decrease in intestinal distention and position of tube head forty-eight hours after intubation.

Not infrequently following a hysterectomy or oophorectomy patients will become distended and present all the signs of bowel obstruction In this type of case again two etiological factors have often been found A paralytic ileus due to localized abscess in the cervical stump or in the retrocaecal area or an atony of the intestinal tract due to surgical trauma Long tube intubation

is the treatment of choice in such cases Although intestinal decompression is usually obtained in twenty four to forty-eight hours, one must remember the possibility of localized abscess which may later have to be drained before the problem will have been solved Intubation is merely one phase in the treatment in such cases and an assiduous attempt made to find the etiological factor

Plastic exudate as a cause of ileus is quite commonly found, particularly following uterine suspension operations or pelvic surgery Tuberculous peritonitis of exudative type would also fall into this group In these cases a loop of bowel becomes adherent to second loop or to the operative site as a result of a plastic exude The interference with the intestinal stream results in the loops of bowel becoming filled with fluid and hence becoming heavy The drag of the weighted bowel produces an angulation or kinking which causes the partial bowel obstruction produced by the exudate to become a complete obstruction In such cases gastro-duodenal intubation by the Levin tube is of very little value. To be successful one must pass a long tube far down the intestinal tract preferably the ileum since ninety per cent or more of such cases involve ileal loops of bowel With the long tube in place, intestinal decompression is rapid so releasing the angulation and kinks in the bowel The continuity of the intestinal stream being re-established passage of flatus or stool is not uncommon Such cases may be completely cured by intubation alone. A certain percentage of these cases later develop adhesive bands which produce bowel obstruction and requires re admission and surgical intervention Generally several months is required before such bands develop if they are going to Every patient subjected to operation is a potential candidate for bowel obstruction due to the development of adhesive bands

ILEUS DUE TO MECHANICAL LESIONS

In this group we classify all cases of ileus or bowel obstruction due to any mechanical lesion whether it be compressing the bowel from within or from without or by interference with the circulation of the bowel In this group, the lesions range from adhesive bands producing intestinal obstruction to mesenteric



Figure 85



Figure 86

Figure 85 Patient T J., Female, White Age 34 Diagnosis Intestinal obstruction—adhesions. Note the degree of intestinal distention of flat film.

Figure 86. Patient T J., Female White, Age 34 Same patient as Figure 85 after intubation. Note the decompression obtained.

thrombosis This group of lesions has been classified in many texts under the heading of simple obstructions and strangulating obstructions The idea being that in strangulating obstructions, prompt surgical intervention is indicated whereas in the simple type of bowel obstruction such as is found in adhesive band obstruction, intubation alone may be all that is required. From an analysis of hundreds of cases we are unable to subscribe to such a classification.[209] We feel that all these cases require surgical intervention to remove the mechanical factor responsible whether it be an adhesive band or a carcinoma of the rectum We shall demonstrate that the only function of the long intestinal decompression tube in such cases is to give the surgeon time to adequately prepare the patient for surgery or make the operative field much easier and the operation simpler The only exception to this is found in those cases subjected to multiple operations in the past with the development of extensive gastro-intestinal adhesions. In such cases so many loops of bowel are adherent to each other and the abdominal wall as well as the liver and

other abdominal viscera that operation would be of little value In such cases, intestinal intubation to carry the patient over the period of blockage of the intestinal stream usually controls the problem for the time being Such patients are subject to repeated attacks of bowel obstruction from adhesions regardless of the surgical procedure employed so that they may be better treated by intubation alone We have successfully employed this procedure in several such cases in whom release of the adhesions would have been impossible Only a long intestinal tube would be of value here as the obstructions are of the multiple short loop variety and would not respond to gastro-duodenal suction drainage

The most common etiological cause for bowel obstruction is the post-operative adhesive band In this type of case intestinal intubation with the long tube will rapidly result in decompression Gas will be passed per rectum and even bowel movements will



Figure 87



Figure 88

Figure 87 Patient H G Female White Age 32 Diagnosis Intestinal obstruction—adhesions. Note distention.

Figure 88. Patient H G Female White Age 32 Decrease in intestinal distention after intestinal intubation All these patients must be operated upon and adhesions cut if patient is to avoid a recurrence



Figure 89



Figure 90

Figure 89 Patient M M., Female, White Age 42. Diagnosis Intestinal obstruction—adhesions. Note position of Cantor tube head eight hours after intubation

Figure 90. Patient L. C., Male, White, Age 35 Diagnosis Intestinal obstruction—adhesions. Position of tube twenty four hours after intubation.

occur Many surgeons then discharge such patients as cured by intubation alone. Reports from many centers [110] as well as our experience at Grace Hospital reveals the startling fact that at least thirty per cent of these return with a second bowel obstruction That this should occur becomes reasonable when we remember that by intubation we have merely released the distention and relieved the angulation of the bowel interfering with the intestinal stream, but we have not interfered with the adhesive band. The band remains as before to again produce obstruction when conditions are favorable For this reason we feel that in any case in which a diagnosis of obstruction due to adhesive band has been made that surgery is indicated after decompression has been obtained The head of the tube will often be found to lie just at the point of adhesion with the result that the operation is greatly simplified Adequate peritonealization of all raw areas will aid immeasurably in preventing a recurrence.



Figure 91



Figure 92

Figure 91 Patient J J, White Female Age 34 Diagnosis Intestinal obstruction—adhesions. Note the degree of intestinal distention.

Figure 92. Patient J J, Female White Age 34 Position of tube head two hours after intubation

Internal and external hernia as a cause of bowel obstruction are quite common Immediate operation is unquestionably the procedure of choice in such cases Intubation has its place however in the pre-operative and post-operative period As soon as the patient is admitted, if a long intestinal decompression tube is passed it will be found not uncommonly that by the time the patient is prepared for surgery that the tube will be well down the gastro-intestinal tract deflating the bowel. This is the usual result in such cases because peristaltic activity in these cases is usually unimpaired or may in fact be increased in an effort to overcome the obstruction A long tube in the bowel is especially important in strangulating types of bowel obstruction from hernia Not only is the bowel often deflated so making operative procedure easier but if resection of the bowel is required because of strangulating hernia with bowel necrosis the presence of a long tube well down the gastro-intestinal tract will furnish an adequate safety valve to protect the suture line In such cases, there is little



Figure 93



Figure 94

Figure 93 Patient J J., Female White Age 34 Same patient as in Figures 91 and 92. Note position of tube head forty-eight hours after intubation.

Figure 94 Patient J J., Female, White, Age 34 Same patient as Figures 91 92, and 93 *Note the excellent visualization of the holes in the Cantor tube.* Note position of the tube head.

or no post-operative distention with the result that leakage at the anastomosis is reduced to a minimum with the proper surgical technic

In lesions within the bowel such as foreign body obstructions (gall-stones, enteroliths) the question of strangulation is not usual. Long intestinal tube intubation deflates the intestinal tract often to the point of obstruction. Operative removal of the foreign body and leaving the tube in- ... to decompress the bowel post-operatively makes the operat... ention a relatively simple matter. In inflammatory les... bowel such as ter *minal ileitis* ... intubation ... e will often carry the patient ... al period ... ult that af... the subsidence ... p ... is necessary ... with x ra ... the ...

such cases has shown promise [211] Certain it is that bowel resection has been disappointing since recurrence in another loop of bowel is not uncommon Here then intubation relieves the obstruction by controlling the distention until the inflammatory process subsides



Figure 95 Patient H M., Male White, Age 60. Diagnosis Mesenteric thrombosis. Bowel resection. Post operative paralytic ileus and adhesive band obstruction (diagnosis proven at successful operation) Tube forty-eight hours after intubation.

Mesenteric thrombosis results in the immediate production of signs and symptoms of a strangulating type of bowel obstruction. Such patients are often in shock and measures to overcome the shock status must be employed before surgery is undertaken This is often a matter of a few hours During this period of waiting intestinal intubation can be very profitably employed to decrease the distention resulting in an easier operation with less handling of the distended loops of bowel. The presence of a long tube in the bowel is highly desirable in all such cases post operatively since resection generally is required. An occasional case can be successfully treated by embolectomy before necrosis has occurred in bowel wall. Even in such cases distention post operatively is the rule By the pre-operative use of a long tube much time can be saved in preventing intestinal distention by removing all swallowed air as well as decompressing the bowel paralyzed by anoxia The tube, again, furnishes adequate protection for the suture line of the anastomosis This becomes then aseptic non surgical enterostomy

Intussusception so commonly found in children requires immediate operation once the diagnosis has been made. During the time the patient is being studied intestinal intubation is of value



Figure 96



Figure 97

Figure 96. Patient H M., Male White Age 60. Same patient as in Figure 95 Film taken on fifth day after intubation. Small amount of dilute barium given to verify diagnosis of band obstruction.

Figure 97 Patient H M., Male White, Age 60. Same patient as in Figures 95 and 96. Marked decrease in intestinal distention. Pooling of barium in small bowel At operation two points of bowel obstruction caused by firm inflammatory process were found in the ileum. Uneventful recovery after dissecting bowel free and peritonealizing.

and leaving the tube in post-operatively prevents post-operative distention The peristaltic waves are vigorous in all these cases with the result that the intestinal tube is carried down to the point of obstruction often in twenty four hours It stops at that point furnishing adequate proof of the mechanical nature of the obstruction. Where the diagnosis is in doubt with a tube in place a small amount of liquid barium may be injected through the tube, roentgen films taken to verify the diagnosis and the dilute barium sucked out The tube may here be used diagnostically as well as therapeutically Wherever the diagnosis has been made, operation as soon as possible is obviously the procedure of choice.

In summary it may be said that all cases of mechanical obstruction of the bowel with the one exception of those cases pre

senting multiple and extensive adhesions from many previous operations, must be operated upon regardless of the etiological factor involved Intubation alone will not cure any of these cases It will often re-establish the continuity of the intestinal stream for the time being, but it only lulls us into a false sense of security since a high percentage of these patients so treated become obstructed at a later date In the event that the patient happens to be in an isolated part of the country where facilities are meagre or in the event that some other pathological process appears at the same time as the recurrence of the obstructive process, the life of such a patient may be needlessly lost.

PATIENTS SUBJECTED TO ELECTIVE OPERATIONS —NON SURGICAL ENTEROSTOMY

There are many cases in which elective operations are performed for known lesions of the small bowel in which formerly preliminary enterostomy was done prior or at the time of resection of the small bowel In any such case, long intestinal tube intubation particularly with a simplified intestinal decompression tube of 18 Fr lumenal diameter obviates the necessity for enterostomy The risk to the patient is thereby decreased both because of the fact that the operative risk associated with enterostomy is removed but also because the long tube being strung along the small bowel to the point of resection greatly simplified the operative procedure by creating a perfect operative field requiring no packs

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CHAPTER X

INTESTINAL INTUBATION IN LESIONS OF THE COLON

THE use of a Levin tube in the treatment of lesions of colon is universally recognized as being of little or no va Although the use of the long tube in the treatment of these lesi appears to be controversial because of Sperlings observations u the competency of the ileocaecal valve, nevertheless there are finite indications for the use of the long intestinal decompres tube in colonic lesions In fact, in some of these the long tube al is all that is required to correct the problem. Just as lesions the right colon and lesions of the left colon require a differ surgical approach so too must the right colon be considered ap from the left colon for purposes of intubation.

LESIONS OF THE RIGHT COLON

Lesions of the right colon lend themselves admirably to treatment by long intestinal tube intubation Since the vast r jority of lesions of the right colon occur in the caecum, Sperlin observations upon the patency of the ileo-caecal valve matt little The passage of a long tube down to the ileo-caecal va will adequately decompress the entire small bowel which has come distended by the lesion at the caecum Fortunately m lesions of the right colon are not complete obstructions so tl peristaltic activity is usually good. In many cases the intestin tube passes through the ileo-caecal valve and into the caecum a ascending colon In such an event not only the small bowel b also the right colon would be decompressed of gaseous and liqu material

In considering the lesions of the right colon, we find fi malignancies Here the obstruction is usually partial with t *result that a long tube can readily be passed to or through t*



Figure 98 Patient C. B., Male, White Age 58. Diagnosis Carcinoma of the caecum. Note distention.



Figure 99 Patient: C. B Male, White Age 58 Same patient as Figure 98. Film taken forty-eight hours after intestinal intubation.

ileo-caecal valve While intestinal decompression is being obtained the patient can be made ready for operation Plasma protein is brought to normal by plasma and blood transfusions Electrolyte balance returned to normal Dehydration corrected At operation resection of the right colon is greatly simplified by the fact that all the small bowel is strung along the tube requiring a minimum of packing and a simplified surgical approach After resection of the right colon, leaving the tube in situ, a non surgical enterostomy is obtained in protecting the suture line. In any case when doing an ileo-transverse-colostomy the head of the tube must be pulled back to the lower jejunum If this is not done the tube is very apt to pass through the anastomotic stoma and into the left colon. The danger here resides in the fact that when the tube is removed the suture line may be torn resulting in leakage. This is particularly apt to occur if a side to-side anastomosis is done Stomal edema at the site of the ileo-transverse-colostomy is not uncommon post-operatively This would result in



Figure 100



Figure 101

Figure 100 Patient M K. Female, White Age 70. Diagnosis Carcinoma of the caecum. Note distention.

Figure 101 Patient M K., Female White Age 70. Same patient as Figure 100 Film taken two hours after intubation. Tube head in the second limb of the duodenum.

bowel obstruction producing small bowel distention The danger to the suture line would be present The presence of a long tube in the upper ileum keeps the bowel decompressed until the stomal edema subsides with a resultant release in the obstructive process

Inflammatory lesions of the caecum frequently accompany terminal ileitis Partial or complete obstruction as a result of the inflammatory process is common The results of resection have been disappointing Long intestinal tube intubation will adequately decompress the entire small bowel. Such decompression may be maintained for three weeks or longer In many such cases the inflammatory process will subside with a resulting release in the obstruction Roentgen therapy may be combined with intubation in the treatment of lesions of this type The results are very promising Resection can always be resorted to if other measures fail A long tube may be used as in malignancies of the right colon Tuberculous lesions, ecum producing obstruction may be tre y intubation ction

Mechanical lesi right col ue to bands or foreign bodies are ted by lo ubation to o through the ileocaec he surgi h whether be to cut the constri remo gn body

colotomy is greatly simplified Colo-colic intussusception can be handled much more easily because of the free access the surgeon has to the lesion with the small bowel collapsed and out of the way If resection is required, an enterostomy is no longer necessary so that the risk to the patient is reduced

Paralytic ileus involving the right colon is part of the generalized paralytic ileus In numerous cases we have been able to demonstrate that the long intestinal decompression tube passes through the ileocaecal valve and into the transverse colon or even sigmoid In this event decompression of the liquid contents of the right colon may be obtained by means of the 18 Fr tube If the ileocaecal valve loses its competency in paralytic ileus a tube down to the valve would adequately decompress the caecum As one moves toward the left colon the intestinal contents becomes more solid and is less likely to lend itself to decompression

In lesions of the right colon with the intestinal tube head in the ascending colon or at the ileocaecal valve concentrated oral feedings are possible Much of the nutrient material in such feedings would be absorbed and available to the patient before the intestinal stream reached the holes used for suction The simplified intestinal decompression tube is well adapted for intubation of lesions of the colon because of its large lumenal diameter as well as the larger size of the holes

Some recent work has been done upon the treatment of colitis by excluding the colon using a long tube Using an air filled balloon tipped tube, the tube head is permitted to pass down to the ileo caecal valve and then the balloon inflated The inflation of the balloon plugs the ileocaecal valve and as a result seals off the colon The fecal stream is aspirated through the tube By so excluding the colon from the fecal stream good results are claimed for this method in selected cases

INTUBATION IN LESIONS OF THE LEFT COLON

Just as the left colon is physiologically different from the right colon and requires a different surgical attack, so also is the problem of intestinal intubation different in lesions of the left colon from those of the right The normal content of the left colon consists of solid fecal material which does not lend itself to decompression from above As early as 1835, O Bierne

by the use of the O'Bierne tube[313] reported many cases of obstructive lesions of the left colon treated by intubation using this large caliber four foot tube inserted from the anus up into the sigmoid. The colon was then inflated with water under pressure in an effort to overcome the obstructive process. Since in the nineteenth century fecal impaction was a not uncommon source of bowel blockage the treatment of the obstruction to the fecal stream by intubation with the O'Bierne tube attained some measure of success. By the same mechanism at times volvulus of the sigmoid was able to be corrected. However, with improvements in our diagnostic facilities and the advent of the roentgen ray a high degree of accuracy in the diagnosis of obstructive lesions of the left colon is now possible. As a result of this and the improvements in surgical technic resections of the colon are relatively common procedures. With the increased knowledge of the obstructive lesions of the left colon it has been realized that a decompressed bowel can be resected and anastomosed much safer than a distended one. Since lesions of the left colon generally are of slow growth the obstruction is often partial for some time before becoming complete and the intestinal distention a rather late feature. In neglected cases patients may be admitted to the hospital greatly distended and dehydrated with a poor electrolyte balance, and low plasma protein and blood count. Such cases require immediate attention in order to prepare the patient for the extensive bowel surgery required. Defunctionizing transverse colostomy has been advocated in some surgical circles as the only method to be used to decompress the intestinal tract in preparation for the surgical intervention. Although this procedure is excellent preparatory to resection of the left colon and primary anastomosis there are types of lesions that can better be handled by intestinal intubation using the long intestinal decompression tube of large caliber. We therefore have two methods of securing intestinal decompression in lesions of the left colon the surgical approach by defunctionizing transverse colostomy and the use of long tube intestinal intubation.

Inflammatory lesions of the left colon can usually be treated by intubation alone. The obstructive process in such lesions is generally not complete although in severe cases it may become

complete Diverticulitis is the most common inflammatory lesion of the left colon We have been quite successful in passing a long intestinal decompression tube (Cantor) into the colon in this type of case In these inflammatory processes there is often a considerable amount of mucous thrown into the left colon with the result that the normal solid stool is not present, but instead a liquid stool is found The edematous bowel wall which is the site of the obstructive lesion becomes increasingly edematous because of the liquid fecal material in contact with it By the use of a long intestinal decompression tube this bowel can be kept empty By keeping the colon decompressed the surgeon is given time to treat the inflammatory process with sulfonamides, penicillin or other antibiotics Most of these inflammatory processes subside with such medical therapy with a resultant release of the intestinal stream A certain percentage of these patients will remain well for years, but many will return with a recurrence of the inflammatory process Such cases will require resection of the bowel The long intestinal decompression tube can be used well in such cases to keep the intestinal tract deflated until the inflammatory process has subsided and the patient put in condition for operative intervention The presence of the entire small intestine strung along four to five feet of intestinal tube keeps the small bowel well away from the operative field. The resection itself can therefore be done with a minimum of effort. Leaving the tube in place post-operative keeps the post-operative distention down as well as acting as a non surgical safety valve enterostomy to protect the suture line On occasion in the repair of a sliding hernia on the left side, the sigmoid colon may be traumatized sufficiently to produce considerable inflammatory reaction A partial obstruction resulting in tremendous distention is the usual sequal The use of a long intestinal decompression tube down to the ileo-caecal valve or more commonly into the colon itself keeps the distention down until the traumatic inflammatory process subsides with a complete resolution of the obstructive process

Foreign bodies as well as impacted feces are not uncommonly found in the rectum and sigmoid colon producing obstruction of the bowel Distention is a prominent feature particularly in the





Figure 102 Figure 103

Figure 102. Patient A. S Male, White Age 58. Diagnosis Carcinoma of sigmoid colon. Note distention.

Figure 103 Patient A. S Male White Age 58. Same patient as in Figure 102. Intestinal tube resulted in adequate deflation of small bowel. Small amount of barium in colon

older age group of patient in which the mechanical obstruction is complicated by an atonic bowel In some cases the fecal impaction has become calcified to form enterogenous stones Some of these as well as some of the foreign bodies cannot be removed from below and require operative intervention At times the diagnosis is in doubt until the abdomen is opened since barium enema studies reveal merely obstruction of the left colon Sigmoidoscopy is of great value in diagnosis if the lesion is within the distance scope of this instrument The use of a long tube to control the intestinal distention while these studies are going on is of great value Since most of these cases have active peristalsis the tube is usually carried rapidly into the colon In the presence of formed fecal material proximal to the point of obstruction, the long tube is valueless insofar as decompression of the colon is concerned but it will keep the small bowel decompressed and so render the operative procedure much easier In cases complicated by atony of the bowel roentgen studies may safely be





Figure 104 Figure 105

Figure 104 Patient A I Female White, Age 60 Diagnosis Carcinoma of the sigmoid colon. Note tremendous intestinal distention.

Figure 105 Patient A. I., Female, White Age 60. Same patient as in Figure 104 Lateral film taken to show the tremendous degree of intestinal distention.

carried out from above with a long tube in place because in the event of the barium making the obstruction complete it can readily be sucked out of the patient

Volvulus constitutes a not uncommon lesion of the sigmoid colon Here certainly a defunctionizing colostomy would not be indicated A long tube in the lower ileum or colon will keep the bowel adequately decompressed following operative intervention as well as creating a more favorable operative field This type of lesion always requires surgical correction

Malignancies of the left colon constitute by far the greatest source of obstructive lesions of this area The obstructive process is generally not complete from the beginning although at times it begins as a complete obstruction In this type of case defunctionizing transverse colostomy is probably the procedure of choice

in preparation for resection once the diagnosis has been made Too often however, patients are admitted with a complete obstruction of the bowel and tremendous distention without a diagnosis of the obstructive lesion having been made. Very often such patients are in very poor condition being dehydrated anemic, and having low plasma protein values In cases of this type, the long tube may be very advantageously used during the time the patient is being studied and prepared for surgery By using a long tube in such cases the intestinal distention can generally be adequately controlled thus giving the surgeon time to make a diagnosis and prepare the patient Once a diagnosis of malignancy of the sigmoid or rectum has been made then a defunctionizing transverse colostomy may be done prior to resection There are many surgeons, however, who leave the long tube in the colon and perform a primary anastomosis without colostomy depending upon the large lumen of the intestinal tube to keep the colon decompressed. In some of these cases the tube head passes through the anastomosis about the third day post-operative and presents itself at the anus When this occurs there is generally no longer the need for a long tube so that the tube can be removed from below



Figure 106. Patient A. I., Female, White Age 60 Repeat film Figure 31 Same patient as in Figures 104 and 105 Note position of tube head in ascending colon and marked decrease in intestinal distention

In intubation of lesions of the left colon there is very little difficulty in passing the long tube into the terminal ileum or very often into the various divisions of the colon The reason this can be done so readily is the fact that in a majority of the cases of obstruction of the left colon there is active peristalsis along

the gastro-intestinal tract As a result of this the downward course of the long tube is very rapid Generally in twenty four hours the tube will be found in the terminal ileum in such cases and in forty-eight hours or by the third day it is found in the colon. We have seen no cases of perforation of the caecum as a result of the distention of the colon since using the long intestinal decompression tube The liquid contents of the right colon lends itself well to aspiration by a tube of the caliber of 18 Fr

It must be emphasized that in any case in which a resection of the left colon is to be done in a patient beyond the age of sixty the preliminary use of the long intestinal decompression tube is of value. In this age group, atony of the small bowel is quite common When this occurs post-operative, it will be found that the defunctionizing transverse colostomy is of very little value In such cases who are generally debilitated and weak to start with and whose condition is further deteriorated by the operative procedure, it may be very difficult or impossible to pass a long tube post-operative because the patient cannot be maneuvered freely It is far better to pass the long tube several days pre-operatively and have it in the ileum before resecting the colon

There is a definite trend in recent years toward doing a resection of the left colon without preliminary transverse defunctionizing colostomy It is felt, in many centers, that with the use of the sulfonamide drugs and streptomycin pre and post operatively that the left colon can be removed without danger of peritonitis It is universally agreed upon that it is not the spillage at the time of operation that produces the fatal peritonitis but the persistent leak at the suture line Meyer and Kozoll[21a] generally do not use the long tube, cecostomy or colostomy for decompression in such cases They feel that the use of succinyl sulfathiazole and the pre-operative cleansing of the colon have all aided in preventing post-operative distention For this reason, they state that they do not fear a "blow-out" at the suture line They advocate the use of a simple Levin tube with gastroduodenal suction to prevent the swallowing of atmospheric air which is considered to be the greatest source of post-operative distention





Figure 107 Figure 108

Figure 107 Note that the mercury has leaked out of the balloon of th tube due to the error on the part of the interne. This was his failure the balloon after inserting the mercury and before passing the t

Figure 108. Patient H. G Female, White Age 38 Note error of mercury due to failure of interne to tie off balloon at the neck of s has passed through the pylorus however Mercury innocuous

whether the patient is to be intubated and then followed gical intervention

If the intubator is acquainted with the potentialities an acteristics of each type of tube, he can avoid many of the that have occurred from time to time in the use of in decompression tubes Most of these errors are the re thoughtlessness on the part of the intubator

When the attending surgeon orders a long intestinal pression tube, he must specify the type of tube he wants the different tubes on the market today, being based different propulsive principle require a different technic cessful intubation. When he specifies on the chart that h a Miller Abbott tube he must know that tube when he and not accept a Harris tube or lately when the Cantor asked for he must not permit a Miller Abbott tube to be u

Having selected the proper tube for the case in question the attending surgeon must examine the tube to be certain that it is not defective and that its various parts are properly attached Failure to do this may lead to errors of this type



Figure 109 Patient H G., Female White Age 38. Same patient as in Figure 108. This is a double error Not only has interne failed to tie off the balloon permitting the mercury to run out, but too much tubing is being passed resulting in coiling of the tube. To correct this, withdraw sufficient tubing to bring the letter "D" at the nose or pass no more tubing for twelve hours.

On occasion, in using the Miller Abbott tube, the metal indicators at the proximal end of the tube are reversed In other words, in the division of the tube where the indicator shows suction the lumen is *really for inflation of the balloon* and where it says inflation the opening is really for suction Failure to check this before insertion of the tube has led to several types of error In several cases, the interne injected the mercury into the side labelled "inflation" with the tube in the stomach Since the indicators were reversed, the mercury promptly ran into the stomach No harm occurred from this error because of the innocuousness of the mercury On many occasions in which mercury was not used when a reversal of the indicators was not recognized a considerable amount of air was injected in an effort to inflate the balloon which would not inflate because it was in the wrong channel. These errors are more annoying than harmful On the other hand on occasion the nurse in charge of the patient, when instructed to irrigate the Miller Abbott tube every three hours, forced the saline solution into the wrong side. The result of this was a tremendous inflation of the balloon with saline If *not* recognized bowel obstruction from this source will result

In using the Cantor tube in which the mercury is inserted into

the balloon before the tube is inserted into the patient the intubator must be certain to express all the air from the tube and tie the balloon off at its neck just above the end of the tube Failure to do this will result in the mercury running out as the tube is being inserted into the stomach Since this tube depends for its propulsive mechanism upon a small amount of mercury trapped in a loose balloon failure to seal the balloon by tying off the neck of the sac can only result in failure

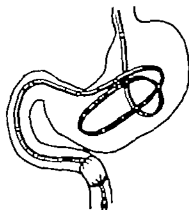


Figure 110. Effect of rushing the double lumen tube. (*From* Johnston C. G Nelson's Loose Leaf Surgery)

In inserting the long intestinal decompression tube errors at times are noted. Do not try to push a large metal end such as is found in a Johnston tube through a narrow nose If a Johnston tube is desired, use a catheter through the nose first and then fasten the catheter to the end of the tube and pull it through backward. In using a Cantor tube remember that you are relying upon a free flow of a highly labile heavy metal Hyperextend the neck of the patient in inserting the tube in order that the nasal passage will run downhill Do not push the tube head uphill into the nose. Let it always run naturally downhill Do not attempt to intubate a comatose patient.

With the tube in the stomach be sure that there is not too much tubing passed at this time To do so means coiling in the stomach and often knot formation in the tube regardless of the type of tube used The Miller Abbott Johnston and Harris tubes are calibrated in centimeters Remember that there is approximately sixty centimeters to carry these tubes well into the stomach In using the Cantor tube we have attempted to make the tube fool proof by making S for stomach P for pylorus, and D for duodenum When the directions call for S to be at the nose in the enthusiasm of passing the tube do not insert the tube to the mark D Proper insertion of the tubes will result in better intubation because coiling will not occur

Failure to keep the tubes well lubricated and the mucosa of the nasopharynx moist in the intubated patient may result in the

lopment of an otitis media as result of irritation in the on of ostium of Eustachian tube Watch for this development and keep tube away from the openings of Eustachian tube do this keep patient off of the side as much as possible, have straight in bed with the neck ante flexed as much as possible uma to the arytenoid cartilages at the time of insertion or esult of continued use of the tube may lead to chondritis es of ulceration of larynx with the development of stenosis e been reported with the use of the Miller Abbott tube To we have not had this occur with the use of the Cantor tube umatic edema of the larynx produced by the use of the Miller ott tube has been reported by Kaufman, Serpico, and Mermer[213] Rupture of an esophageal varix was also reported by same authors It would seem desirable in intubating patients whom there is a suspicion of esophageal varices to use a tube out any metal parts Morrison[214] has described a case of oid chondritis where the tube was left in place too long Wansteen has reported two cases with injury to the arytenoid tilages due to prolonged intubation Iglauer and Molt[217] have orted ten cases of injury to the larynx as a result of the prese of the tube. Eight of these cases developed laryngeal sten- Because of this the intestinal tube st be left in place only as long as ded and removed as soon as possible

The formation of knots in the tube a result of too rapid passage requires removal of the Miller Abbott tube ause the holes for suction are distal the point of knotting In the Cantor e the development of such knots does t require the removal of the tube if it s passed through the pylorus Since tube is single lumen additional holes n readily be made in the tube and permitted to pass downward into the stomach Decompression can dily be obtained in this fashion In the removal of a tube with knot when the knot has reached the naso-pharynx it should drawn out through the mouth and cut off Knotting in the gle lumen tube does not impair the efficiency of the tube in any



Figure 111 Knot formation in a gastro-duodenal tube This is the result of initially passing too much tubing into the stomach.

resection of the bowel has been done and the balloon is proximal to the anastomotic site, then removal of the tube can be accomplished by gently but steadily pulling upon it. When the distended balloon reaches the duodeno-jejunal flexure or the pylorus, pulling upon the tube generally ruptures the balloon permitting an easy removal. If the distended balloon is found to be distal to the anastomotic site, pulling upon the tube will tear open the anastomosis and result in peritonitis. In a case of this type the surgeon has two alternatives. He can cut off the tube and permit it to be excreted from below or he can open the abdomen and compress the gut containing the inflated balloon between his hands. The rupture of the balloon then permits an easy removal from above. If the surgeon should elect to permit the balloon to pass out through the anus he must watch the patient carefully to be certain that the inflated balloon is not obstructing the bowel. If the patient becomes distended again a second tube is passed to decompress the distended bowel. With the decrease in the intestinal distention in the bowel at the site of the inflated balloon there would be a definite alteration of gas pressures between the inflated balloon and the bowel. In other words now the pressure of the gas in the balloon would be greater than that in the lumen of the bowel. The law of diffusion of gases is such that the gas would now tend to leave the balloon and pass into the lumen of the bowel. Re-establishment of peristaltic activity or a small enema would then result in the passage of the balloon. The second tube would then be removed



Figure 113. Note gas distention in balloon of Cantor tube. The pressure of the gas in the balloon causes the mercury to assume a globular shape. Condition recognized by flat plate. At operation to release obstruction, bag compressed manually and broken. Withdrawal of tube easy. Uneventful recovery of patient.

way, but it completely obstructs the Miller Abbott type of tube

There have been many reports in the literature of knot formation in gastroduodenal tubes as well as long intestinal decompression tubes Among these are the reports of Billings,[216a] Paviot, J , and Levrot, M ,[216b] Molfino,[216c] and Uriburu[216d] describing knotting in gastroduodenal tubes, McKittrick and Sarris,[216e] Hinson,[216f] and Brenizer[216g] have reported knot formation in the Miller Abbott tube. This same accident can occur however with any type of tube so that the intubator must be able to recognize it and institute the proper treatment



Figure 112. Knot formation in Miller Abbott tube. Note knot just proximal to the end of the tube. Note the tremendous distention of the balloon with intestinal gases pushing the mercury toward the base of the balloon. Verified at autopsy Tremendous distention of balloon with gas found and knot completely obstructing the tube so that the gas could not be evacuated.

In a very small percentage of cases in which the intestinal tube is permitted to remain in the gastro-intestinal tract for longer than five days, it may be found that the balloon tipped intestinal tubes take up gas into the balloon from the bowel. Because of this, check up roentgen studies may show that the balloon is more inflated than the amount of air inserted or the presence of air may be noted in the balloon of the Cantor tube where no air was supposed to be The presence of this air in the Miller Abbott or Johnston tubes usually creates no problem as it can readily be aspirated through the inflation channel. On occasion however the Miller Abbott tube may develop a knot proximal to the balloon.[216h] In that event, the distention of the balloon with intestinal gas cannot be evacuated When this complication occurs the treatment depends upon the type of case involved and the exact position of the balloon If a

resection of the bowel has been done and the balloon is proximal to the anastomotic site, then *removal of the tube can be accomplished* by gently but steadily pulling upon it When the distended balloon reaches the duodeno-jejunal flexure or the pylorus, pulling upon the tube generally ruptures the balloon permitting an easy removal If the distended balloon is found to be distal to the anastomotic site, pulling upon the tube will tear open the anastomosis and result in peritonitis In a case *of this type the surgeon* has two alternatives. He can cut off the tube and permit it to be excreted from below or he can open the abdomen and compress the gut containing the inflated balloon between his hands The rupture of the balloon then permits an easy removal from above *If the surgeon should* elect to permit the balloon to pass out through the anus he must watch the patient carefully to be certain that the inflated balloon is not obstruct*ing the bowel If the patient* becomes distended again a second tube is passed to decompress the distended bowel With the decrease in the intestinal distention in the bowel at the site of the inflated balloon there would be a definite alteration of gas pressures between the inflated balloon and the bowel In other words now the pressure of the gas in the balloon would be greater than that in the lumen of the bowel The law of diffusion of gases is such that the gas would now tend to leave the balloon and pass into the lumen of the bowel Re-establishment of peristaltic activity or a small enema would then result in the passage of the balloon. The second tube would then be removed



Figure 113 Note gas distention in balloon of Cantor tube The pressure of the gas in the balloon causes the mercury to assume a globular shape. Condition recognized by flat plate. At operation to release obstruction bag compressed manually and broken. Withdrawal of tube easy Uneventful recovery of patient.

If the gas filled balloon is not obstructing the bowel de would eventually result by the same process When the accident occurs in the Cantor or Harris tube, the air can removed except by breaking the balloon

The intestinal decompression tube may become plugge intestinal contents as noted by ton[214] who reported a plugg the tube by orange pulp given patient. Hinson has reported a type of obstruction to an int tube by a blood clot. This woul mit fluid to be injected into the from above but would not perm piration of the intestinal cor Such accidents are particularly occur in tubes with a small lu diameter for decompression

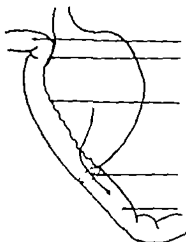


Figure 114 Sketch of conditions following Polya type of partial gastrectomy Note position of true gastric stoma. To intubate a patient of this type ambulation is imperative Raising the foot of bed and turning the patient on right side would result in the tube head being trapped in blind proximal loop

In intubating a patient wh had a gastric resection or gast terostomy remember that the g stoma is now along the greater c ture In using the Cantor tube d turn the patient on his right side raise the foot of the bed as n normal stomach To do so w result in the head of the tube trapped in the proximal loop All these patients must sit u ambulate to insure successful intubation with a tube head taining mercury

In using an air filled balloon-tipped tube remember the p bility of an excessively inflated balloon causing obstructio itself The reports describing this occurrence are of inte Once the distention has subsided following successful intuba a re appearance of the distention with the suction active sh create a suspicion that balloon blockage has occurred Deflate balloon to note whether the obstructive signs disappear If do the diagnosis is obvious if the obstructive signs do not appear the patient must be operated upon

The only time that the long tube is fastened to the nose of the patient with adhesive is in those cases in which further downward progress is not desired. Where an anastomosis has been done and the surgeon does not want the balloon to pass through the anastomosis the tube must be drawn well back from the site of operation and fastened to the nose of the patient. Folley[218] reports that with pleating of the intestine upon the tube, leaving the balloon of an air filled tube inflated with air may result in perforation of the bowel due to pressure. In such cases, remember to deflate the balloon when using a Miller Abbott or Johnston tube. In using a Cantor tube no such precaution need be taken as there is no air in the balloon.

Birnbaum[218a] has reported a case of inflammation of the vermiform appendix by the metallic mercury which ran out of a Miller Abbott tube. The patient was admitted to the hospital with an obstructing malignancy of the recto-sigmoid. A Miller Abbott tube was introduced a few days before surgery and mercury then injected into the balloon. The balloon ruptured and permitted the mercury to escape into the intestinal tract. In twenty four hours mercury was found in the appendix in a fairly large amount. When colostomy was performed the appendix was found to be acutely inflammed. It was removed. Gross examination of transversely cut appendix showed globules of mercury in the appendix. Microscopic examination verified the diagnosis of acute appendicitis.

Warren and Cattell[218b] have reported a rather unusual accident during intestinal intubation with the report of a case of intussusception of the small intestine over an indwelling Miller Abbott tube which resulted in complete intestinal obstruction.

BALLOONS OF INTESTINAL DECOMPRESSION TUBES TRAPPED IN THE GASTRO-INTESTINAL TRACT

With the introduction and widespread acceptance of the long intestinal decompression tube in the treatment of intestinal distention, it was inevitable that unforseen complications would

arise. One of the uncommon complications, but a highly important one, is the inability of the intubator to remove the intestinal tube after its use is no longer required. With one type of tube,[11] an incidence of three percent for this unforseen complication has been reported, although elsewhere in this chapter we have noted that all tubes characterized by the presence of a balloon along the shaft have at one time or another had this accident. Although this accident has not occurred with the simplified intestinal decompression tube (Cantor) another accident of similar nature has occurred. This is the loss of the balloon containing the mercury which had been tied off improperly

The studies of Cantor Phelps, and Esling upon the effects of the various gases found in the gastro-intestinal tract of patients with intestinal obstruction has led to a clear understanding of the cause of this accident. These studies have demonstrated conclusively that all balloons are permeable to all the intestinal gases. Some types of intestinal tube balloons, such as those made of latex are five times as permeable to various gases as are those made of neoprene rubber

In an analysis of all cases in which the intubator was unable to remove the intestinal decompression tube, one feature was common to all That is, the presence of air or gas within the balloons of these tubes in an amount far greater than should be present. *The only exception to this occurred in those cases in which* the balloon was accidentally filled with fluid which could not be withdrawn In the Miller Abbott tube or other double lumen tubes, in which air is injected into the balloon for the purpose of stretching *the bowel wall* the air-propulsion *mechanism is depended* upon for successful intubation. It is normally possible to withdraw the air from the balloon thus collapsing it and rendering withdrawal of the tube simple Unfortunately at times knotting of these double lumen tubes occurs with the result that the air that was injected into the balloon remains trapped. In Fig 112, note the knot in a Miller Abbott tube proximal to the balloon and note also the tremendous distention of the balloon containing mercury Rupture of the bowel resulted in this case as a result of the markedly dist… d Since nitrogen constitutes

eighty percent of this air trapped within the balloon of these double lumen tubes, and since nitrogen is exceedingly slowly dif fusible through the wall of the balloon the consequences to the patient may be serious This is especially so because of the high degree of permeability of such latex balloons to carbon dioxide and hydrogen sulphide gases Because of this permeability, there is a marked increase in the size of the balloon as the percentage of carbon dioxide and hydrogen sulphide gases within the bowel of a patient with intestinal obstruction is usually far greater than that within the balloon Since the balloon contains only the air that was originally injected and since the percentage of carbon dioxide in the air is only 0 03% whereas the percentage of carbon dioxide in the bowel ranges from four to fourteen percent in bowel obstruction the diffusion of this gas into the balloon of the intestinal tube is only to be expected By the same mechanism hydrogen sulphide gas diffuses from the bowel, which may con tain one to ten percent of this gas, into the balloon which, being filled with air, contains none

Since the balloon of the Harris tube is six inches long as much as 125 c.c of gas may diffuse into it. When this occurs the balloon is so large that it cannot be removed from above

The simplified intestinal decompression tube (Cantor) is made with a balloon two and one half inches long placed at the tip of the tube Our experience with this type of tube has been that the incidence of the balloon becoming filled with gas was approximately 0 3% when a latex balloon was used The reason for the smaller incidence even when latex balloons were used is the thickness of the wall This thickness being 0 24 mm is four times that of the Miller Abbott or Harris tubes and hence rend ered this balloon much less permeable Since discontinuing the use of latex and substituting a mixture of neoprene and latex we rarely see any such complication Although we have never noted any difficulty in withdrawing this type of tube, the only acci dent that has occurred is of a different origin and easily cor rected This accident is the loss of the tied-off balloon filled with mercury or mercury and gas The cause of this accident is the application of the tie which seals the mercury within the balloon, to the wrong spot The application of this tie below the end of the tube instead of over the point of application of the balloons to the

tube invites trouble By incorrectly tying below the end of tube, on occasion when the tube is removed, the balloon con ing the mercury tears off and remains within the gastrointes tract On three occasions this lost balloon was found to co gas when a flat plate of the abdomen was taken to localiz In three cases personally followed the balloons were excreted rectum

EFFECT

The effect of a distended gas filled balloon within the ga *intestinal tract depends upon the type of case being intubated* the patient has been intubated for any type of intestinal disten not the result of mechanical obstruction, there may be no ill e whatever as a result of this gas filled balloon The caliber of bowel is such that in the vast majority of cases such gas fi balloons even when attached to the tube can be passed per rec if released This is especially prone to occur when the gas intestinal tract has been decompressed. In this event, there wo be an outward diffusion of gas from within the balloon into the compressed bowel so that when the tube was ultimately pa per rectum the balloon would contain very little of the gas *114a illustrates this type of case Note that the entire intest* tube has passed through the gastrointestinal tract and the t head is in the transverse colon In this patient the tube was creted per rectum two days later

If the bowel is not decompressed then a much longer pe of time would be required before any of the gas from within balloon would diffuse into the bowel In this latter event a sec tube can be passed in order to secure the decompression of bowel which would make it possible for the balloon to deflate the mechanism of diffusion of gases

In any case in which there has been a mechanical type of testinal obstruction it may be impossible for the gass filled b loons to pass the narrowed area Once the obstruction has b released the balloons readily pass through and are excreted p rectum The distended balloons may cause a partially obstruc bowel to become completely obstructed This is especially apt

occur if the balloon is larger than two and one half inches long. If the balloon has been lost within the gastro-intestinal tract of a patient with a partial obstruction on a mechanical basis, a ball valve type of obstruction might occur. Gas and some liquid stool frequently pass around the distended balloon through the partially obstructed area. This may give one a false sense of security.


Figure 114a

The most serious effect of such trapped or lost balloons occur in patients who have had bowel resections or bowel surgery of any type. In such cases, if it is not recognized that the intubator's inability to remove the tube is due to a distended balloon and if the balloon is distal to the anastomotic site, the process of withdrawing this distended balloon through the operated area might tear the bowel with the inevitable leakage and peritonitis.

Rupture of the bowel by a gas filled balloon is uncommon. Rupture of the bowel by a balloon filled with fluid by error has occurred as has complete obstruction of the bowel by the same error. Injury to the bowel at the duodeno-jejunal flexure as well as injury to the esophagus has been reported to the author by surgeons using air filled double lumen tubes when attempting to forcibly remove them.

Treatment

The treatment for this complication must be individualized. No specific treatment is applicable to all cases. The vast majority of patients in whom there is no decrease in the caliber of the bowel can easily be cured by cutting the tube off at the nose and permitting it to pass per rectum. This it will always do provided there

is no obstruction to the bowel distal to the tube In the event that the balloon has been lost from the simplified intestinal decompression tube (Cantor), whether with mercury alone or with mercury and air, the treatment will depend upon whether the patient has been previously decompressed. If the bowel has been decompressed such balloons will always pass per rectum In the three cases observed at our hospital the time required for these balloons to pass were twenty four hours, three days and fourteen days respectively

If the bowel has not been decompressed a second tube may be passed in order to obtain satisfactory decompression. The lost balloon will then pass per rectum if the bowel has not had its lumen narrowed as a result of a partial obstruction. In our experience the failure of such balloons to pass per rectum in a reasonable period of time is presumptive evidence of partial bowel obstruction, and must be treated accordingly

Under no circumstances should any attempt be made to remove an intestinal decompression tube in any case in which bowel surgery has been done until a flat plate of the abdomen has been taken to determine the position of the tube. Pulling an inflated balloon through the site of bowel surgery is to invite disaster If the balloon is distal to the site of bowel surgery permit the tube to be passed per rectum If the balloon contains gas and is proximal to the site of bowel surgery decompression of the circumjacent bowel will invariably result in sufficient gas being lost from the balloon to permit its removal from above. A rare case may require operation. If operated upon compression of the distended bowel containing the gas filled balloon will rupture the balloon and render the removal of the tube from above simple. To obtain this compression the surgeon need merely grasp the distended bowel between his palms and squeeze upon it.

An absolute preventative to the development of this complication when using the Cantor tube consists simply in applying the tie of twenty five pound pull silk or fishline to the end of the tube over the point of application of the balloon to the tube Before tying this tie tightly the stylet of a twenty-one or twenty two gauge needle must be inserted through the last hole and into the balloon The tie is then tightened over the stylet very tightly

Then when the stylet is removed, a safety valve vent is left through which any gas diffusing into the balloon can escape but the mercury remains trapped

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CHAPTER VII

NURSING CARE OF PATIENT WITH INTESTINAL INTUBATION

WE ALL recognize the fact that the patient whose intestinal tract is being intubated by the long tube is usually a very sick person Generally one in whom there is a profound alteration in the normal physiology of the gastro-intestinal tract as well as an alteration in the chemistry of the blood The nursing care of this type of patient resolves itself down to the problem of caring for such an individual who in addition to his primary illness is being taxed by problems inherent in intestinal intubation. The various tubes used today for intestinal decompression vary in the amount of nursing care required to take care of them Some of the tubes such as the Miller Abbott tube require considerable nursing attention in order that its suctioning lumen remain patent while others such as the Cantor tube requires little or no nursing attention The nurse must be informed as to the type of tube being used and just what to expect in the way of attention to it

Up to the time that the patient is intubated the nursing care of the patient will follow the usual routine for the specific illness in question Sedation of the patient and the relief of pain is one of the important tasks of the nursing staff In the intubated patient however this task takes on lesser importance and at times keeping the intubated patient sedated is undesirable Some of the problems that arise in the intubated patient begin with the moment the tube is brought to the room of the patient

When the intestinal decompression tube is brought to the room of the patient in the absence of the surgeon the nurse in charge should check it to be certain that it is the tube ordered for that patient Then the tube must be checked to be certain that it is clean and has been sterilized I think it is well for her to run an applicator into the lumen of the tube to make sure that

none of the sterilizing solution is still present. It might also be well for her to rinse the lumen of the tube with tap water as an added precaution. Although it would seem that such precautions are carrying things too far, yet, recently failure to do this resulted in the death of a patient. In the case in question the following data was obtained:

> H S, primipara, age 35, a white female was admitted to the hospital because of pregnancy. The conditions were such that Cesarean section was decided upon and this was done. Post-operatively there was an unusual degree of intestinal distention. A diagnosis of atonic ileus was made and a long intestinal decompression tube ordered to be inserted. This was done. Within twelve hours, the patient went into shock and in forty eight hours was dead. Necropsy on this patient revealed a gangrenous type of gastritis of an extreme degree. A fairly large amount of lysol solution was found in the gastric cavity. In checking back over the possible sources for this to get into the stomach, it was found that the girl in charge of the intestinal tubes had neglected to flush out the lysol solution in which the tube was sterilized. The result was that a large amount of lysol solution was introduced in the stomach of the patient with the tube.

The tube having been checked and found to be clean, it is now ready to be used. It was formerly current practice to ice the tube before using. When a long tube is ordered in most hospitals the tube is sent up in a dish of ice. We discourage this practice in the use of the Cantor tube as we have found much better results without attempting to freeze the tube by inserting it at room temperature. The effect of a cold tube in the stomach of a patient may result in decreased gastric motility with the result that it will not pass through. A tube at room temperature is tolerated by the stomach much better.

After the tube has been passed into the stomach of the patient the nurse in charge must see to it that all the following orders relative to the change in position of the patient are carried out

to the letter She must not improvise If the instructions call for the foot of the bed to be elevated twelve inches, she must see to it that the foot of the entire bed is elevated twelve inches and not just the bedspring which may be cranked up The ability of the nurse to follow orders to the letter in these maneuvers and to pass only sufficient tubing as indicated will invariably result in successful intubation. In those hospitals in which there is an intubation team ' all this is then done by the internes and residents on the team The nurse can, in that event, devote her entire attention to the patient

With the tube down into the gastro-intestinal tract of the patient the care of the remaining portion of the tube and its method of feeding downward into the patient is important It must always be remembered that the nasal mucosa and the pharyngeal mucosa are not accustomed to the presence of a foreign body such as a tube — particularly a dry, rubber tube The presence of a foreign body of this type always results in an irritation of the nasal and pharyngeal mucosa with an outpouring of secretion The discharge is very prone to crust upon the tube so that a further downward movement of the tube becomes very painful and difficult as long as the crusts are present. This can be avoided to a great extent by instilling two percent ephedrine in oil with one half percent pontocaine into the side of the nostril in which the tube lies. In addition the portion of the tube just beyond the nose must be moistened for a distance of three to four inches with mineral oil By keeping the tube moist there is much less frictional irritation as it is being passed

The pharyngeal mucosa must be kept moist with liberal intake of saline solution Giving of water freely by mouth washes out the stomach and the chloride with it. By using normal saline by mouth there is less chloride depletion in this way The position of the tube in the pharynx should be checked from time to time and an effort made to keep the tube from being over the Eustachian ostia for too long a time This can be done by turning the head from side to side and ante flexing the neck. Too long a contact with the ostia of the Eustachian tube is apt to create sufficient irritative edema as to result in occlusion and often otitis media

The nursing care of patients who are known to be smokers requires more attention than in non smokers In the former group, there is generally a pharyngeal irritation to a greater or lesser degree even before the introduction of the tube, and such patients invariably present overactive glands along the tracheo-bronchial tree The presence of a foreign body such as a long tube for any length of time further increases the irritation and hence there is an increase in the glandular secretory activity The accumulation of this secretion in the naso-pharynx and in the bronchial tree may result in bronchiolar plugging unless the nurse sees to it that all secretions are promptly evacuated The most effective method of accomplishing this is motion of the patient. By moving the patient and even ambulating him wherever possible the bronchial secretions are readily brought up This is particularly *important if the patient is in any way dehydrated for here the* stage would be set for mucous plug formation and atelectasis. Although the same sequence of events may occur in non-smokers yet it does so to a much lesser degree because there is less pharyngeal irritation and bronchial secretion prior to intubation To avoid this complication of intubation, then two things are required adequate hydration of the patient to prevent mucous plugs, and motion of the patient either in bed, or preferably by ambulation to facilitate expectoration of the secretions

The after-care of the long intestinal decompression tubes, after intubation varies with the type of tube being used The small lumenal diameter of the decompression lumen of the Miller Abbott tube requires it to be irrigated with saline every three to four hours to prevent plugging by the liquid particulate matter found in the gastro-intestinal tract. Be sure before you start that the indicator suction is really connected with the decompressing lumen otherwise the irrigating solution is apt to go into the inflated balloon *The single lumen simplified decom*pression tube being of an 18 Fr lumenal diameter does not require any such nursing care The fluids that the patient drinks being readily aspirated by the tube keeps it flushed clean at all times. The size of the holes also in this latter tube being so much larger than in any of the other tubes and the elliptical shape of the holes as well as the fact that holes are strung along a dis-

tance of two feet of tubing renders them practically immune to plugging

Constant attention must be given to the source of the negative pressure. This is particularly important in using the bottle method as advocated by Wangensteen It is of little value to have an intestinal tube down to the ileocaecel valve, if the source of negative suction at the other end is not working Leakage in the tubing and the various connections of the bottles must be watched for

Any patient that is being intubated is losing rather large amounts of fluid by suction In some cases as high as five thousand cubic centimeters of liquid particulate matter may be removed in a twenty four hour period Failure to correct the constant loss of fluid would soon result in an increased dehydration with its resultant dangerous consequence An accurately kept intake and output chart is very important Remember that in charting the output by suction that the oral fluid intake must be deducted because most of the liquid intake is soon aspirated by the tube The replacement of the fluid loss by intravenous alimentation is the procedure of choice Frequent checks on the blood chlorides is essential in any patient being intubated The drinking of water during intubation tends to wash out chlorides from the stomach This must be restored by intravenous chlorides Giving saline solution by mouth to these intubated patients is helpful in preventing some of this chloride loss from the stomach by washing After the intestinal tube has passed well down the gastro-intestinal tract and the intestinal distention is under control then oral feeding of concentrated liquid diet is permissible clamping the tube for two hours after each feeding Some of this intake will be absorbed by the patient with a result that less fluid is required intravenously If clamping of the tube results in any return of the distention, this practice is stopped at once Ice cream, jello beef broth and liquified foods of any type may be given at the proper time in this way It will be found much easier to bring the serum protein to normal by oral protein feeding in this way than by amino-acids given intravenously

The output of urine should be carefully scrutinized daily A urinary output of eight hundred to one thousand c.c of a fairly normal concentration 1 020 or less is good assurance that there

is good hydration With a urinary output in this range there will be no nitrogenous retention because of fluid loss. When the urinary output falls below this level and the concentration of the urine increases, intravenous fluids should immediately be increased. The degree of nitrogenous retention can readily be ascertained by non protein nitrogen determinations at times when indicated

Avoid oversedation in the intubated patient Many patients that are intubated are apprehensive partially because of their primary illness and partially because of the presence of the intubation The presence of the long tube in their nose furnishes a constant reminder to the patient that he is very sick. The individual reaction to this thought varies greatly Some patients accept this calmly whereas others become quite upset emotionally An occasional few become antagonistic and will not permit the tube to remain in place If the patient refuses to have a tube in place and removes it whenever possible, such a person should be considered a poor subject for intubation Here the tact and understanding of the surgeon and particularly the nurse in charge can do much to make the patient co-operative. Many of these people, if handled tactfully will permit intubation All patients intubated must be treated at all times to calm their apprehension A small amount of sedation is permissible but keeping the patient sedated results in a decrease in motion of the patient. This is highly undesirable The patient should be told that with the tube in place that motion can be free and most cases can be ambulated. If these patients are soothed during the early period of intubation the great improvement in the intestinal distention within twenty four hours usually results in such a feeling of well-being that most patients become co-operative There is an occasional case however that does not lend itself to intubation because of the marked aversion of the patient to an intestinal tube It is better to recognize this early and plan some other form of intestinal decompression

The irrational patient may be quite a problem to the nursing staff in keeping the tube in place Many of these patients during their period of unclear consciousness pull out the tube For tunately cases of this type are very uncommon. However when

they do occur a change in the normal procedure is required Fastening the tube to the nose of the patient must be resorted to in such cases and restraint of the patient in bed in the various positions desired Since these people often thrash around in bed one need not concern himself about the motion of the patient With a patient lying quietly in a comatose state however adequate nursing means frequent changes in position of the patient By this we mean not only from side to-side but also on his face and then back In any event these patients must not be permitted to remain in any one position for too long a period of time

In the removal of the tube, remember that twenty four feet of bowel is plicated along four or five feet of tubing A slow but steady pull upon the tube will usually result in its easy removal Permit fifteen minutes or more for this process If there is any stoppage of the tube it is most likely the result of sphincteric spasm Giving the patient a sedative and leaving him alone for a time will generally result in a release of the spasm and a simple removal of the tube If the long tube is found to emerge through the anus, it is better to pull it out that way

CARE OF THE TUBES AT CENTRAL SUPPLY

When the intestinal tube is returned to the central supply it will be found to be covered with mucous and intestinal *contents* The porous latex balloon containing the mercury must be stripped off and discarded. The tube is then thoroughly flushed and rinsed in water It is then put in disinfecting solution, lysol or some other solution and permitted to remain sufficiently long to sterilize it Then the tube must again be thoroughly flushed out with water and carefully washed until all traces of the disinfecting solution has been removed. The tube is then hung up to dry After drying new balloons are re applied to the end of the tube in the usual fashion In the Miller Abbott Johnston and Harris tubes the balloons are fastened to the shaft of the tube with silk. In the Cantor tube a special cement has been devised which swedges the balloon to the end of the tube without the necessity of tying To do this, one coat of the cement is applied to the end of the dry tube and permitted to dry for four to six hours

A second coat is then applied and the balloon neck pulled onto the end of the tube This is permitted to stand for twelve hours. The tube is now ready to be used It is essential, before applying the cement that all powder has been removed from the end of the tube

Do not permit organic solvents such as alcohol, benzine, etc., to come in contact with the tube, since the cement which holds the bag to the tube is soluble in organic solvents and the attachment of the bag to the tube will be weakened

The use of a Vienna pattern nasal speculum serves very well to dilate the end of the bag and facilitates introduction of the tube into the bag

CHAPTER VIII

TYPES OF SUCTION AND METHODS OF USE

AN ADEQUATE source of negative pressure suction at the proximal end of the tube is as important as getting the tube down the gastro-intestinal tract It is quite obvious that a long tube far down the gastro-intestinal tract that satisfies all the necessary requirements for successful intubation, will be of little value if the source of negative suction is poor or actually not working In that event the suction device would be worse than useless because it would completely block the tube and prevent the increased intraluminal pressure from forcing the intestinal contents into the tube and so out

Four types of negative suction are being successful employed today

SIPHONAGE SUCTION

The very simplest form of siphonage drainage of the gastro-intestinal tract merely consists in passing a long intestinal decompression tube into the gastro-intestinal tract and dropping the proximal end over the side of the bed into a bottle When a tube of large luminal caliber (18 Fr) such as the simplified intestinal decompression tube reaches the stomach there is an immediate outpouring of gastric contents The force with which the gastric contents shoots out of the tube is often so great that it literally spurts out The reason for this is the great increase in intra-gastric and intra abdominal pressure found in any case of intestinal distention The stomach rapidly empties merely by virtue of the tube being present in that viscus and because of the elasticity of the gastric wall When the tube head leaves the stomach and passes down the gastro-intestinal tract however different conditions obtain In the small bowel there is also a marked increase in intraluminal as well as intra abdominal pressure that forces the intestinal contents into the lumen of the tube

and so out by siphonage However, since the intestinal contents in any case of intestinal distention of moderate degree is a mixture of gas and liquid and not liquid alone, bubbles of gas enter the lumen of the tube with the liquid intestinal contents When this occurs the siphonage is broken and does not become re established until the bubbles of gas are evacuated To prevent this

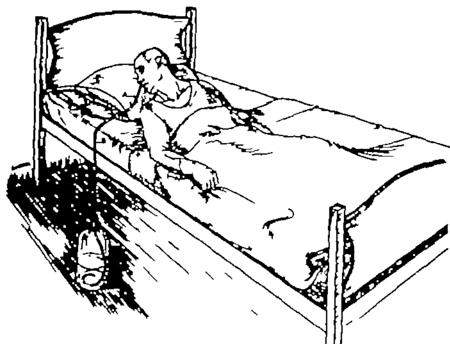


Figure 115 Simplified siphonage unit proposed by Leithauser (A) Long intestinal decompression tube connected to glass "T" tube (B) Opposite end of "T" tube connected to rubber tube of larger lumen whose opposite end is immersed in a bottle on floor End of tube below water level in the bottle. (C) Syringe to prime unit. (*From* Leithauser D J J.A.M.A.)

occurrence Leithauser [319] has devised a simplified priming device for use with the method of siphonage in the treatment of intestinal distention

One great advantage of the simple siphon method using a priming device, is its utter simplicity which necessitates a minimum of nursing care Cumbersome equipment requiring constant attention is not required, and since Leithauser is an ardent advocate of early ambulation, this procedure can readily be put into action without disconnecting or removing any apparatus The

patient merely gets out of bed and walks carrying the tube with him This simplified siphonage unit as described by Leithauser in 1945, consists of a glass "T" tube connecting the long intestinal decompression tube (A) to a rubber tube of a large lumen (B,) whose opposite end is immersed in a bottle below water level The bottle is placed on the floor beside the bed A short rubber tube is attached to the vertical arm of the T' tube The patency of the long intestinal decompression tube is determined by applying a clamp on B' and then injecting and aspirating water with a large syringe through ' C " The clamp on B is then released and water is injected into the bottle on the floor to prime the unit A clamp is then placed on C and the unit is ready to function In the event that gas passing through the intestinal tube breaks the siphonage, priming the unit as described readily re-establishes the siphonage The unit should be flushed through with water once a day to prevent plugging by liquid particulate matter aspirated from the gastro-intestinal tract. By using a glass T tube of the same luminal diameter as that of the rubber tubing leaks are prevented and equal suction pressures are maintained throughout

CONTINUOUS SUCTION BY WATER DISPLACEMENT METHOD

This method of continuous suction drainage is one of the simplest and oldest methods used today It was early used by Matas and Bassler early in the twentieth century Ward in 1925 again called attention to this method of suction drainage and modified the apparatus The greatest impetus to the use of this method of obtaining negative pressure at the end of the gastro-duodenal tube to suction out intestinal contents was the work and writings of Wangensteen and his co-workers [230] They further modified the apparatus in an effort to so simplify it that the set up could be made easily available in any hospital and set up on very short notice The principle upon which this apparatus is based is the fact that if a bottle is filled full of water and connected to a second bottle by rubber tubing which is air tight that the flow of water from the upper bottle to the lower one leaves a vacuum in the upper bottle which acts then as a negative

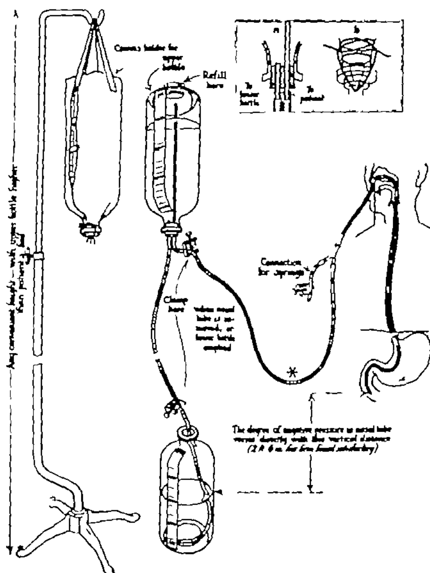


Figure 116. Apparatus for continuous suction as advocated by Wangensteen. This was later modified many times to incorporate slight improvements. (*From* Wangensteen, O H West. J Surg., *40* 1 1932)

pressure exerting a suctioning force to be applied to the end of a gastro-duodenal tube At the time this apparatus was introduced its chief function was gastro-duodenal suction to drain the upper gastro-intestinal tract At present this simple method is also used as a suctioning force to aspirate the entire gastro-intestinal tract by being attached to a long intestinal decompression tube When this method is properly used and supervised by one who understands the mechanics involved, excellent results are obtainable. Unfortunately many surgeons and nurses do not quite understand the mechanics involved and the necessity for air tight equipment so that in many hospitals, as a result of unfortunately poor results, the method has fallen into disrepute My own experience with this method has been excellent With proper supervision of the nursing staff and frequent checks on the equipment to be certain that it is properly hooked up and air tight, as good results are possible with this equipment and at lesser cost than with any other available today The apparatus consists of the following

1 Two large glass bottles holding 4,000 c.c.
2 A two-hole rubber stopper which fits one of the bottles tightly
3 A canvas sling to hold one of the bottles in an inverted position
4 A standard to hold the upper bottle five feet above the floor
5 About fourteen feet of rubber tubing of ¼ lumen
6 Two glass tubes one four and one 16 inches long
7 Several screw clamps

To assemble the apparatus as simply as possible the canvas sling is fitted over one of the bottles and this bottle is filled with water The glass tubes are so placed in the two-holed rubber stopper that the longer glass tube extends almost to the bottom of the bottle to be inverted The shorter glass tube is so placed to extend just within the mouth of the bottle The rubber stopper containing these two tubes is then fitted tightly into the mouth of the bottle to be inverted and hung up side-down on the standard at a distance of six feet from the floor The short glass tube is connected by a six foot piece of rubber tubing to the

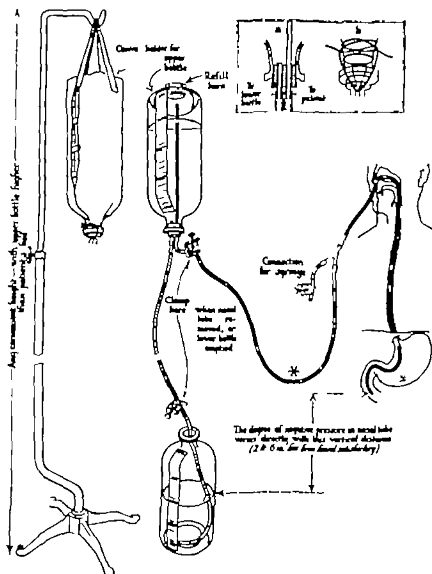


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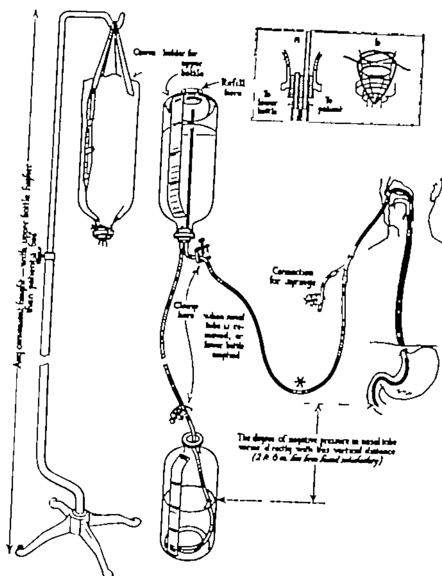


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3. A canvas sling to hold one of the bottles in an inverted position.
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5. About fourteen feet of rubber tubing of ¼" lumen.
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7. Several screw clamps.

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second bottle which rests on the floor and contains two to three hundred c.c. of water. The rubber tube must be below the water level in the bottle on the floor. This leaves a vacuum in the upper bottle thus creating a negative suction pressure which is transmitted to the end of the intestinal decompression tube. This is basically the mechanism utilized to produce a continuous negative suction pressure utilizable for decompressing the gastro-intestinal tract. From this simple set up, as time went on, modifications were introduced by Wangensteen and many other workers. One of the best modifications was the placing of a collecting bottle between the long glass tube which transmits the negative pressure and the intestinal decompression tube. By so doing and using a graduated bottle it is very easy to measure the amount of gas and material withdrawn while at the same time inserting a protective mechanism in the event that the bottles are improperly set up to prevent the water from passing into the patient by mistake. In addition to this protection the stop-gap-bottle prevents the intestinal mucosa from being exposed directly to too great a suction from the upper bottle. This latter consideration is purely theoretical however as Paine has shown that a suction pressure of 1000 c.c. of water had no injurious effect upon the mucosa. In no case either in experimental animals or at autopsy was there any evidence that the mucosa of the bowel had been sucked into the holes and so become necrotic or injured in any way.

One of the newest and commercially available apparatuses utilizing this water displacement principle to create a vacuum is the equipment of Fritz. This is an automatic drainage and aspirating apparatus capable of continuous suction. Its safety feature is the elimination of all valves and cocks which might interfere with the proper operation of the equipment. There is a specifically designed rotary valve mounted between the bottles, which automatically controls the flow of water suction and pressure and is closed except when the bottles are in a vertical position. An automatic spring lock engages and holds the movable parts of the machine in proper position. The bottle connections cannot be reversed which eliminates any possibility of injecting air instead of withdrawing it to reduce distention. To insure

positive results in the use of this equipment it should be tested This is accomplished by clamping off the suction tube to the patient and checking all the couplings to insure that they are tight and that the rubber stopper is firmly in place in the suction bottle Now, the bottle containing the water is turned up and after a small amount of water runs into the bottom bottle the machine should hold water in the upper bottle for an indefinite period This will prove that all the couplings are tight. If after waiting several minutes, bubbles rise in the top bottle, then it signifies a leakage in the valve This can be corrected by turning the adjustment nut a few turns to the right so putting more pressure on the valve spring After testing the machine remove the clamp from the decompression tube and attach to the suction tube on the machine with a glass connector The machine is now providing adequate suction When the apparatus is tight and the intestinal decompression tube in the proper location the condition of the patient governs the time elapsed between turning over the bottles If the machine stops functioning the tube must be withdrawn a few inches and passed in again with rotation and the patient given some water to drink By so doing function will begin again Never use a clamp on the suction tube from the machine when the apparatus is in use Air must escape freely from the end of the shaft opposite the suction end of the shaft

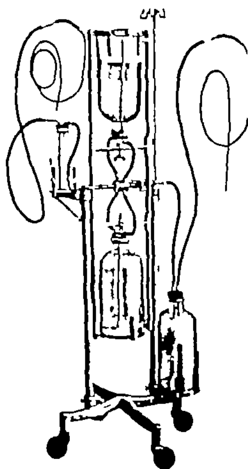


Figure 117 Fritz suction unit. This is an efficient unit utilizing the water displacement method to produce a negative suction pressure

same rating as the pump It is essential in the use of this equipment that a collecting bottle be interposed between the patient and the pump This pump requires no attention other than a drop of oil on its bearings about once a week if it is being operated continuously

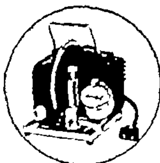


Figure 119 Stedman pump This is a noiseless efficient source of negative pressure It can be operated continuously

In recapitulation it must be noted that regardless of the negative suction pressure employed it must be remembered that constant vigilance is needed to insure that it is operating correctly at all times and that the suction is correctly applied. A long intestinal decompression tube far down the gastro-intestinal tract is of no value without an adequate source of negative suction pressure at its proximal end

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CHAPTER XIV

RESPONSIBILITY OF THE SURGEON IN THE USE OF INTESTINAL INTUBATION

IT MUST be emphasized that the long intestinal decompression tube is an instrument like a hemostat, and will only be of such value in any case as the ability of the surgeon behind it. With the advent of the "intubation era" in the treatment of intestinal obstruction many surgeons have lost sight of this fact and in many hospitals any patient admitted with a distended abdomen was intubated first and then a period of waiting adopted while the tube was supposed to cure the patient. Unfortunately many patients died during this waiting process with the result that unwarranted aspersions were cast upon this aid to our therapeutic armamentarium. In recent years, however, it is being increasingly realized by all thinking men that if properly used the long intestinal decompression tube can be of inestimable value while if ineptly used it can be dangerous. The brain of the surgeon and that alone is the deciding factor.

Any patient with intestinal distention is a candidate for intestinal intubation as is also any patient who formerly would require an enterostomy preliminary to bowel resection. On being confronted with a case of intestinal distention the surgeon must decide which type of case is involved. In the event that a diagnosis of mechanical bowel obstruction is made then the surgeon must decide whether there is any strangulation of the bowel or not. We feel that all cases of mechanical obstruction must be operated upon, but the preliminary use of the long tube for several hours or days pre-operatively does much to improve the condition of the patient as well as rendering the operation much simpler by collapsing the distended bowel. Only a surgeon of experience can decide just when to operate in any specific instance. In the event of a strangulating type of obstruction, operation must be performed as soon as possible. However a non-strangulating

obstruction particularly in the inflammatory distention group may safely be deferred for several days while the patient is being adequately prepared. *A nicety of judgment on the part of the* surgeon is required for best results When the long tube is used in this fashion as an aid to surgery, one may reasonably expect excellent results When, however, the patient is treated by intubation as a non strangulating obstruction and an interval of several days is permitted to elapse while intubating the patient and it is found that the case in reality was one of strangulation of the bowel, the results are apt to be disastrous The tube should not be blamed The surgeon alone is culpable for using *poor surgical judgment. With the use of good surgical judgment* the long tube has a wide range of usefulness in the gastro-intestinal tract Above all however it is an intestinal decompression tube

A reasonably exact diagnosis having been made and intubation having been decided upon, it may not be possible at the moment to decide when surgical intervention will be indicated The progress of the case and the day to-day changes or at times the hourly changes will dictate just when surgery is to be under *taken if the distention is amenable to surgical treatment.* The surgeon must see his patient at frequent intervals during the first few days. The progress of the case cannot be relegated to the interne or resident The entire picture may change completely in a six hour period Whosoever undertakes to intubate a patient must be prepared to spend time with the patient until the clinical course is clear Unwillingness to do so or relegating this function to one not well trained or surgically seasoned, can only lead to poor results

It is the responsibility of the surgeon to examine every tube before it is passed. Preferably the tube should be passed by the surgeon himself There are times in which the proper use of the long tube is as important to the patient as is the operation itself An expertly performed operation may be valueless without adequate intestinal decompression *The proper selection of* a tube that will best satisfy the needs of the specific patient must be made by the surgeon. The tube must be examined to be certain that the central supply of the hospital has sent up the specific

tube ordered by the surgeon It must also be examined to be certain that the balloon is securely fastened, since all the long intestinal decompression tubes in use today have a balloon fastened somewhere along the distal end of the tube. A loosely fitted balloon will come off in the bowel causing valuable time to be lost The tube must be inspected to insure its being clean and properly washed No trace of sterilizing solution must remain within the lumen of the tube.

Having checked the patient and the tube, now the decision must be made as to how much mercury is to be used in the balloon. The illness of the patient and the size of the patient are important considerations A small emaciated woman would not require the same amount of mercury as would a tall robust man A patient with a paralytic ileus requires a different amount of mercury than a patient with active peristalsis Cardiospasm creates a problem which may be solved by an increase in the amount of mercury used Anywhere for four to ten cubic centimeters of mercury may be used in the balloon The smaller amounts for small and cachetic patients and larger amounts for larger and active patients With cardiospasm and paralytic ileus, a larger amount will usually result in an easier passage of the tube because of our dependence upon the mercury in the head of the tube to carry it downward In such cases little or no peristaltic activity is present Here, again, the judgment on the part of the surgeon is required for best results

Once the tube has been passed the surgeon must select that form of negative pressure most suitable for the case in question There is much individuality in the selection of the source of negative suction pressure Whether siphonage or a mechanical source of negative pressure is to be used the surgeon must check it carefully to insure that it has been properly set up and is air tight A tube down to the ileocaecal valve will be of no value to the patient if a poor source of negative suction pressure is applied to its proximal end The type of suction employed may be determined in some cases by the utilization of early ambulation When this is to be utilized in treatment simplicity in our suction device is desirable because the patient will be in-and-out of bed many times a day necessitating connecting and disconnecting the suc

tion device Unless good nursing supervision is available, the simplest possible source of negative suction pressure to make the procedure of connecting and disconnecting fool proof is most desirable

The removal of the long intestinal decompression tube should be done by the surgeon himself In the vast majority of cases the removal of the tube is a very simple matter On occasion however, due to sphincteric spasm or knotting in the tube or passage beyond the point of bowel anastomosis, the removal of the tube may require care and judgment. Here is one problem in which 'speed is not the watchword' All tubes should be withdrawn slowly If arrest of withdrawal occurs, stop and wait for one hour if needed then try again. Any patient who has had a bowel resection should not have the tube withdrawn without a check film to determine whether the tube has passed through the anastomosis If it has, it may be better to permit the tube to pass through and remove it per rectum This is particularly true if a side to-side anastomosis was done

The passage of the long intestinal decompression tube is merely treatment for one phase of the medical or surgical problem Namely the problem of intestinal distention Attention must be given to the other problems incident to the specific illness. If the case is to be a surgical one the patient must be built up to *be in the best possible condition for surgery The correction* of anemia so often associated with intestinal distention as a result of neoplastic disorders in the gastro-intestinal is important. Transfusions may have to be resorted to in an effort to correct the blood deficiency as rapidly as possible The surgeon must decide whether the patient is to have large infrequent transfusions to replace lost blood or small frequent one to stimulate hema topoiesis Plasma protein determinations are important in any case to be resected We try wherever possible to bring the plasma protein level above 5% before surgery A low plasma protein level is too often responsible for poor results irrespective of the skill of the operator Intravenous aminoacids aid in re storing lost water and at the same time supply the basic protein molecules. Practically, we have *found it very difficult to raise* the plasma protein by the use of intravenous protein therapy

Protein hydrolysates given by mouth or via the tube are more effective in this regard, and the best of all is liquified protein foods given by mouth. In preparing the patient for an elective operation where the obstruction is incomplete oral feeding of protein is the method of choice. Protein foods, even meat, may be liquified and given orally or via the tube in any case except those patients markedly distended. The tube being in situ much can be accomplished by such oral or tubal alimentation clamping the tube for brief periods of time after giving the protein to permit absorption.

Blood chloride determinations at frequent intervals are essential in any case being intubated. Patients with intestinal distention have some degree of water and chloride loss into the bowel and tissues. This fluid and chloride loss is further increased by the suction which not only removes all the fluid from the gastro-intestinal tract but also drinking of water by the patient washes out the gastric chloride still further. In order to maintain the proper electrolyte balance, intravenous fluids and chlorides must be used in the proper amounts. The normal daily supply of five to nine grams of chloride may have to be increased to eighteen grams in order to compensate for the loss by suction.

The level of the blood chlorides must be kept at a fairly normal point if failure in intubation due to decreased intestinal motility is to be avoided. There are many surgeons who advocate the use of injections of 5% saline solution in order to treat intestinal distention. This has been successful in some cases by virtue of the increase in intestinal motility which hypertonic saline injections are said to produce. We have never found it necessary to use hypertonic saline in this way. On several occasions, however we have been unable to successfully intubate patients with intestinal distention whose blood chloride level was markedly decreased. In all such cases, intubation was immediately successful when the blood chlorides were restored to the normal level. It is our practice as a result of these experiences to check the blood chlorides in all patients in whom intestinal intubation is delayed. It is surprising how often the chloride level will be found to be low and it is equally surprising how rapidly a successful intubation ensues when a normal chloride level is reached.

Adequate hydration is essential with intestinal intubation. Under normal circumstances the human being is automatically kept in water balance. The normal checks and balances set up in the body keeps the normal person well hydrated. Under normal circumstances any water loss unaccompanied by loss of sodium or chloride results in a dryness of the mouth and pharynx. This gives rise to a sensation of thirst. In response to this sensation water is consumed in sufficient quantity to restore the loss of water. This same mechanism is called into play without any loss of water if there is an increase in sodium chloride in the body.

In the patient suffering from intestinal distention or as a result of bowel obstruction there is a loss of water and salt by vomiting as well as a loss into the gastro-intestinal tract itself. Thus even prior to intestinal intubation these patients may be dehydrated or suffering from alkalosis or acidosis as a result of the disease process from which the patient is suffering. There is also a decrease in available water taken by mouth in such cases prior to intubation as a result of vomiting and distention and after intubation all water drank is suctioned out.

The average normal adult is said by Hoffman[221] to have the following intake and output:

INTAKE		OUTPUT	
Water and other beverages	1200 c.c.	Urine	1500 c.c.
Water of solid foods (about 70%)	1500 c.c.	Feces	200 c.c.
Water of oxidation (about 12 c.c. per 100 cal.)	300 c.c.	Sweat	300 c.c.
		Insensible water loss—	
		Skin	700 c.c.
	3000 c.c.	Lungs	300 c.c.
			3000 c.c.

Of the above items the water and beverage intake is very elastic depending upon the eating habits of the patient. On the output side of the ledger the quantity of water available for urine formation is most elastic. The amount of water available for urine to excrete nitrogenous wastes is the difference between the total intake and that excreted from all other portals. In other words the more water that is used up as sweat or in the feces the less is available for urinary excretion. Under normal circum-

stances the thirst mechanism previously described keeps the patient sufficiently hydrated to permit a urinary output of 1000 to 1500 c.c. The specific gravity of such urine is 1 015 When there is a deficient intake of water either due to disease or suction there is very prone to be insufficient water for urinary excretion A minimum of 500 c c. of water is required daily to excrete the nitrogenous products formed during a twenty four hour period A decrease in available water below this level results in nitrogen retention even in the presence of a normal renal function

The main cation responsible for the osmotic pressure of the extracellular fluid is sodium This is present in a concentration of 330 mmg per 100 c.c. of plasma The main anion is chloride and it is present when measured as sodium chloride in concentration of 575 to 630 mmg of sodium chloride per 100 c.c of blood plasma The measurement of whole blood chloride has been shown by Hoffman and Osgood[222] to vary directly with the degree of anemia The normal whole blood sodium chloride ranges between 450 and 509 mmg of sodium chloride per 100 c.c if the hemoglobin concentration and hematrocrit are normal With severe anemia however, the normal range increases from 503 to 555 mmg of sodium chloride per 100 c.c With such anemia a whole blood determination of 450 mmg instead of being normal would actually be low and indicative of dehydration. For this reason whole blood chloride determinations must be correlated with the blood count or the plasma chloride determination must be used alone

Generally when sodium and chloride are lost to the body a corresponding amount of water is also lost resulting in the maintenance of a normal concentration of sodium and chloride in the extracellular fluid With high obstructions, however or with gastro-duodenal suction there is a considerable loss of gastric juice containing sodium chloride and hydrochloric acid This loss results in a few days if not replaced in a marked dehydration in an already depleted patient and since the chloride loss exceeds that of the sodium more sodium is left in the body resulting in a condition of alkalosis

In low intestinal obstruction or with the long intestinal decompression tube down in the terminal ileum the fluid loss is a

mixture of water, sodium chloride and sodium bicarbonate The dehydration in this type of case is accompanied by a greater loss of sodium resulting in a relatively increased amount of chloride in the body The result of this shift is acidosis or the loss of sodium and chloride may be about equal with no change in carbon dioxide combining power resulting

For these reasons whenever a patient is intubated such patients must be carefully studied to maintain the proper state of hydration and electrolyte balance, in addition to keeping up the nutrition and vitamin requirements. In general it may be said, that if the patient excretes 1000 to 1500 c.c of urine daily of a specific gravity under 1 018 they are fairly well hydrated. To accomplish this all fluid removed from the patient by suction is measured and an equal amount of water plus 2000 to 3000 c c. is returned daily In addition frequent checks of the sodium chloride plasma level the non-protein nitrogen, and the carbon dioxide combining power must be made Any alteration in the values obtained may readily be compensated for by an increase or decrease in intravenous saline. To maintain an adequate protein level protein hydrolysates can be given orally and whole blood and plasma intravenously In addition an attempt should be made to keep up the vitamin requirements of the body in order to avoid vitamin deficiencies Our practice has always been to give vitamins with our glucose and saline in the proper amounts

It is only by constant vigilance and attention to details that the best results of intestinal intubation can be obtained The close co-operation of an internist and surgeon will help immeasurably in controlling all the special details required during the process of intestinal intubation

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CHAPTER VI

THE ROLE OF THE ROENTGENOLOGIST IN PATIENTS TO BE INTUBATED

THE roentgenologist may play a very important role in the management of the patient to be intubated The best interests of the patient demands that the radiologist be used as a consultant and responsible for all phases of radiological management and not merely used as a technician to take and diagnose x rays Ideally every case to be intubated should be considered a problem of an intubation team the members of which are a surgeon, an internist and a radiologist By so doing experts in the solution of the various problems that arise in the intubated patient would pool their resources in the solution of every problem

A large percentage of the patients that the radiologist is called upon to examine radiographically have already had the benefit of a complete radiological study and the diagnosis has been made In this group the patient is usually being intubated as a prophylactic measure prior to operation. As a general rule such patients are not completely obstructed so that peristaltic activity is good For example a patient with a carcinoma of the caecum not producing complete obstruction has had a radiological diagnosis made and is now admitted for intubation prior to operation A brief review of the previous radiological report is often of value as at times the radiologist may call the attention of the surgeon to some gastro-intestinal abnormality that may hinder or complicate the process of intubation In addition the tonic state of the stomach and the speed of emptying of the stomach and small bowel as noted on the five hour film is suggestive to the intubator of what he might expect in the speed of downward passage of the tube The actual technic of intubation in itself in such cases is usually very simple The vast majority of such patient are easily intubated Often we do not maneuvre these

patients at all, but merely pass the tube into the stomach and permitting the patient to be ambulatory let the tube go on downward with his ingested food In this type of case, the radiologist can supervise the course of the downward passage and tell us just when the tube head reaches its goal in such case, namely — the terminal ileum The surgeon now takes over and resects the right colon and anastomoses the terminal ileum to the transverse colon The radiologist again comes into the picture when the surgeon considers it time to remove the tube A survey of the abdomen at this time is of great value The radiologist can tell us now whether the tube, despite being pulled back at the time of the operation has moved through the anastomotic stoma and is found in the colon If this has happened, it might be better to permit the tube to emerge from the anus rather than drag the tube head through the anastomosis This is particularly dangerous in a side to-side anastomosis or if any air has gotten into the balloon by diffusion of gases An injury to the suture line at this time may result in a leak with its resultant consequences. Not only do we expect the radiologist to tell us where the tube head is prior to removal of the tube, but also whether there is any intestinal stasis as noted roentgenologically If the radiologist tells us that the tube is in the ileum and that there is no abnormal distention of the small intestine as seen radiographically, we can consider it safe to remove the intestinal decompression tube, but not before

Many patients are sent to the hospital for the management of intestinal obstruction and distention but the diagnosis of the etiological factor has been made prior to admission. For example obstruction as the result of an incarcerated hernia presents no diagnostic radiological problem The function of the radiologist in cases of this type where the diagnosis is known would be to tell the surgeon the degree of intestinal distention as noted radiographically Often the radiologist can tell us whether the obstruction is high or low from the gas pattern alone. The degree of intestinal distention and the supervision of the downward course of the tube are valuable aids to the surgeon Many of these cases require special procedures in order to insure successful intubation This is particularly the case if the Miller

Abbott or Johnston tubes are being used At times regardless of the manœuvres employed by the intubator, the tube head persistently remains in the stomach At this juncture, the radiologist may be called upon to try and 'feed the tube through the pylorus' under fluoroscopy At times this can be successfully done by the radiologist A great many Miller Abbott and Johnston tubes have been passed in this way If the Mayer technic or the Abbott stylet are used to secure successful intubation, again the radiologist must supervise the intubation which is done under fluoroscopy

In any case of intestinal distention to be intubated, even when the diagnosis of the obstructing lesion is known the radiologist fluoroscopically screens the chest Much valuable information is forthcoming by so-doing Cardiac enlargment or arrythmias can readily be noted This is particularly important in cases of auricular fibrillation where emboli not uncommonly find their source At times herniation of the stomach will be noted through the diaphragm and into the thorax In this type of case the usual manueuvres of passing a simplified intestinal decompression tube that utilizes mercury would require a change in technic. Turning this type of patient on his right side and raising the foot of the bed would only result in the tube head passing into the thoracic portion of the stomach and remaining there High lying diaphragm aortic aneurysm sub-phrenic abscess all may be called to the attention of the surgeon by the radiologist and may change the technic of intubation

After intubation has been successfully carried out the downward progress of the tube and whether it is progressing downward as it should can be noted by the radiologist The presence of knots or kinks in the tube can be called to the attention of the surgeon by the radiologist The degree of decompression obtained in the serial films taken is knowledge of the greatest importance to the surgeon Only a properly trained radiologist is in a position to distinguish the variations in normal or the degree of intestinal distention as noted radiographically A persistent closed loop of bowel which is distended despite adequate intubation in the remainder of the gastro-intestinal tract is important to know about Finally with improvement in the degree of intestinal distention noted both clinically and radiographically the

radiologist can tell us whether it is safe to remove the intestinal tube from the radiographic point of view, i e whether little or no gaseous distention remains

A third type of case is one in which the patient is admitted to *the hospital with his abdomen greatly distended and vomiting* and the diagnosis of the type of intestinal distention or the etiological factor responsible for it has not been made prior to admission In this type of case the radiologist really comes into *his own It is he that can usually tell the surgeon just what the* trouble is and where it is. Good radiological consultation is almost indispensable in this type of case The radiological management of a case of this type often requires a variety of procedures A careful chest survey and a scrutiny of the heart, lungs mediastinum and diaphragm is of course the first procedure. Often the diagnosis can be made by this alone. Metastatic lesions in the lungs readily betray the source of the obstruction Vascular accidents as result of cardiac pathology can readily be suggested by the roentgen appearance of the heart Neoplastic processes in the mediastinum call our attention at once to the type of difficulty we are dealing with. Gas under the diaphragm or evidences of sub-phrenic abscess readily permits the surgeon to properly classify the patient and institute proper treatment with the intestinal intubation Changes in the intubating technic may also have to be made because of pathology in the chest Evidences of marked cardiac enlargement may make it impossible to put the patient into Trendelenberg position for the first maneuvre of intubation Such patients often become quite cyanotic and require ambulation to secure successful intubation

Following the survey of the chest a survey of the abdomen both fluoroscopically and radiographically may and usually does reveal intestinal distention by gas and liquid indicative of intestinal stasis radiographically It should be noted here that the presence of gas in the gastro-intestinal tract in many early cases of bowel obstruction need not occur Bouslog in 1943[illegible] demonstrated rather well that it is possible to have bowel obstruction without there being any radiographic evidence of gas in the gastro-intestinal tract The gas itself does not indicate in-

testinal stasis Appreciable amounts of gas is frequently found in the small bowel in patients under sedation even before operative intervention Post-operatively, of course, there may be considerable gas in the gastro-intestinal tract as the usual finding and does not mean bowel obstruction From the above it should be evident that the previously held idea that the presence of gas in the small bowel was abnormal and indicated intestinal stasis whereas the presence of gas in the colon was normal, is not quite true radiographically The characteristic feature of the gas pattern in the intestinal tract is its shiftiness or changeability from day to day or even from hour to hour There is usually, with a persistent pathological stasis or retention of gas or fluid in one or more loops of bowel a changeability or the assuming of a variety of patterns The radiologist is aware of this and draws his conclusions accordingly At one time, examination may reveal one single loop of intestine which is persistently filled whereas the next day rows of bowel are filled with gas and liquid It is this latter type of case that is known as "stepladder appearance" of the small bowel which is supposed to be pathognomonic of a small bowel obstruction We should like to emphasize that this 'stepladder appearance is a late stage in the process of intestinal stasis and that the characteristic of early bowel stasis is the marked variability of the gas pattern Very often taking a *roentgenogram* with the patient in the erect position demonstrates a definite fluid level in the loops of gas filled bowel A roentgenogram of considerable gas in the small bowel and little or no gas in the colon is highly suggestive of a small bowel obstruction The presence of gas in the small bowel and colon does not necessarily indicate colonic obstruction as considerable gas may normally be found in the colon

Following the survey of the abdomen the radiologist may investigate the colon by barium enema Barium by mouth to study the small bowel further is definitely contra indicated at this stage Following intestinal intubation and decompression of the small bowel then the small bowel may safely be studied by giving barium by mouth or via the tube in order to localize the site and character of the lesion in the small bowel With the tube in situ

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any signs of stasis of the barium can readily be corrected by aspirating the barium mixture before a complete blockage is created

Prior to such small bowel studies with the tube in situ, it is often considered wise to give the patient a barium enema and study the colon When one remembers, that most of the malignancies of the bowel producing obstruction occur in the colon it is only reasonable to assume that many of the obstructive lesions will be found by so doing A barium enema can safely be given to any obstructed patient except where there is a suspicion of perforation of the colon or impending perforation In the event that the patient is suffering from diverticulitis or ulcerating malignancy of the colon with beginning circumjacent abscess formation or in the case of colonic fistula the use of a barium enema is contra indicated Doing this diagnostic procedure at such a time might complete the perforation resulting in general peritonitis. The radiologist is often able to point out the presence of this type of lesion by the presence of a pneumoperitoneum not otherwise explainable or the presence of a localized pneumoperitoneum At times following a perforation of an obstructing diverticulitis a well localized abscess may present itself radiographically with gas and a definite fluid level

In the event that the barium enema if done, does not permit the radiologist to make a diagnosis then the investigative study may have to wait until the patient has been decompressed so that oral barium may be given safely

At times the patient will present all the characteristic physical and radiological signs of bowel obstruction and yet the lesion producing it may be extrinsic to the gastro-intestinal tract The history if well taken will often cast suspicion on the urinary tract or retroperitoneal area as a source of a reflex paralytic ileus. If such is the case either intravenous or retro-grade pyelography may have to be done before a definite diagnosis of the etiology of the intestinal stasis can be made

From the preceding it should be evident that in any case of intestinal stasis that is to be intubated the cooperation and all the resources of the radiologist must be used for the best interests of the patient. No x ray tec[illegible] surgeon can possibly evalu

ate all the varied maneuvres that may be required of the radiologist before a definite diagnosis can be made

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CHAPTER XVI

INTUBATION IN INFANCY AND CHILDHOOD

INTUBATION of infants and children presents many problems that differ from the adult. The range of lesions producing intestinal distention in children is a very small one. The tremendously vast majority of cases to be intubated will be found in the inflammatory *distention group using the same classification* as for adults to be intubated. Paralytic ileus as a result of a ruptured appendicitis constitutes by far the most common lesion of childhood requiring intubation In a recent report from the Children's Hospital Penberthy, Noer and Benson[214] have found that eighty five percent of all children intubated *were ill with appendicitis* or its complications In effect then the inflammatory distention group constitutes the largest group to be intubated in childhood and the same problems arise in children as in the adults in the same group As in adults, most of these cases can be handled by intubation alone but an occasional case will early develop a mechanical obstruction due to a plastic exudate or to the adherence of a knuckle of bowel to the inflammatory mass A percentage of the cases in this group become candidates for the development of a mechanical obstruction due to adhesive bands.



Figure 120. Patient D G., White, Male, Age 4 Diagnosis Diffuse peritonitis—paralytic ileus. Note the distention.

The next most common type of case in childhood requiring intestinal intubation appears in the atonic ileus group This group is a small one when compared with the inflammatory distention group Retroperitoneal lesions such as hematomas, fractures of the spine and pelvis, renal lesions and occasionally pneumonias constitute the chief etiological factors. Extra peritoneal trauma is an occasional factor In this group as in adults, intestinal intubation with the long tube is all that is required to completely cure the intestinal distention Such cases should never be operated upon. As in adults, enterostomy is not of much value as it drains only one loop of bowel



Figure 121 Patient D G White, Male, Age 4 Note decrease in intestinal distention. In this case, an 18 Fr Cantor tube was passed without difficulty Note position of tube in twenty four hour film. The readily compressible tube head and absence of all metal parts made it possible to pass this 18 Fr tube on this four year old.

In the mechanical distention group intussusception is generally diagnosed before intestinal distention becomes a problem with the result that prompt surgical intervention quickly cures the patient before the need for intubation arises In a neglected case, however, where resection of the bowel is required intubation as a prophylactic measure to protect the suture line is an excellent precautionary measure. In congenital atresias of the small bowel producing intestinal obstruction the size of the patient is such that only the smallest catheter can possibly be passed into the stomach Gastro-duodenal drainage in such cases is usually all that is required. Surgical correction is the only procedure possible and should be done as soon as a diagnosis is made. Adhesive bands as a cause of mechanical obstruction is rather infrequent in childhood The main source for such bands

in childhood would appear to be due to the late effects of the inflammatory distention process

Many of the problems in passing a long intestinal decompression tube in adults are not found in children By using a 12 Fr tube we have found it possible to pass the simplified intestinal decompression tube through the nose of two to three year old children. In using a tube of this type a large luminal diameter is available for decompression. The small size of the decompressing lumen of the double lumen Miller Abbott tube constitutes a real disadvantage in the use of such double lumen tubes in childhood This same difficulty was noted by Penberthy, Noer and Benson. Most children tolerate intubation quite well if properly handled An occasional young child will have to be restrained



Figure 122. Tube head of Cantor tube in child size This is a twelve Fr tube. Note size of holes for decompression.

The anatomy of the upper gastrointestinal tract is much simpler and devoid of many of the traps found in the adult. As a result, there is much less difficulty in intubating the average child.

There is considerable variation in the length of the esophagus and the stomach depending upon the age of the child. This is of importance in calibrating the intestinal decompression tube, particularly if a free use of check films or fluoroscopy is not utilized In examining a large number of children and measuring the various portions of the upper gastrointestinal tract the following measurements were arrived at Average distance from external nares to the cricoid cartilage in children is six inches The esophagus is four inches long in infants and eight inches long in young children The stomach was measured from the esophageal opening to the pylorus along the lesser curvature The following measurements were obtained At age five week—9 cm (3 6 inches) at age two years—10 5 cm (4 2 inches) at age three years—10 5 cm (4 2 inches) at age eleven—12 5 cm (5 inches)

Utilizing the above anatomical data, it is a relatively si matter to know just where the tube head is at all times Ca passing the initial length of tubing will prevent coiling in stomach The Miller Abbott tube used for infants and chil is a 12 Fr diameter But when one considers that only one of this diameter is available for decompression, we are left less than a 6 Fr lumina ameter for decompres Our simplified intestinal compression tube, being a gle lumen tube, permits utilize an entire 12 Fr lu for decompression Usi tube of this type, excellen compression is obtained little danger of plugging o lumen of the tube. The used for children is four long since it has been f that this length is sufficie carry the tube head well the gastro intestinal tract. importance of this is rea when it is noted that in sixty-six percent of case intestinal distention in chi was gastro-duodenal drai effective at Children s pital In thirty three pe of the cases a long inte decompression tube wa quired before the inte distention could be adequ controlled. The Miller Abbott infant tube is calibrated in meters as in the adult The simplified intestinal decompre tube (Cantor tube) is calibrated according to the various

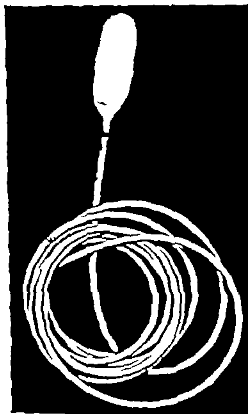


Figure 123 Cantor tube. Children s size. Tube is four feet long Two series of four holes each for decompression Can readily be passed through almost any nose. Use 2 c.c. to 4 c.c. of mercury in the balloon depending upon the size of the child.

is at the external nares, the balloon will be in the stomach. The letter "P" is placed nineteen inches from the end of the tube. When the letter "P" appears at the nose the balloon will invariably be found at the pylorus. The letter "D" is placed twenty-four inches from the end of the balloon. When the letter "D"

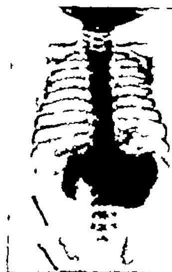


Figure 124

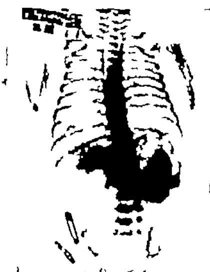


Figure 125

Figure 124 Roentgenograms of child five days old. Thirty-minute film. Note the simplicity of stomach. Angulation at pylorus absent. Maneuvering of patient with this type of stomach not required. (*From* Bouslog, J S Radiology 39 252 1942)

Figure 125 Infant's stomach. Note how readily tube could pass through the funnel outlet (pylorus) of the stomach. (*From* Bouslog J S Radiology 39 252, 1942)

appears at the external nares, the balloon should be five inches along the duodenum. By properly utilizing these markings, the intubator is in a position to know just where the tube is at all times. Much valuable clinical data is made available to the intubator by an examination of the material aspirated. With the marking "D" at the nose and pure bile being aspirated we can be reasonably certain even without x ray that the tube head is in the duodenum.

When the tube has been passed into the stomach it is not usually necessary to maneuver these small patients as we would adults to insure successful intubation. The small size of the

stomach and the fact that usually the greater curvature and the pylorus are about on the same horizontal plane creates more favorable conditions for intubation Most of these children, if not restrained, move about freely in bed The result of all these factors is a definite simplification in the ease of successfully intubating children Once the tube has left the stomach, the tonus and peristaltic activity found in the gastro-intestinal tracts of children, when combined with the constant motion, carries the tube well down into the small bowel.



Figure 126. Stomach of infant. Nine days old. Note funnel out let of simple stomach. (From Boulog, J S Radiology 39 252, 1942)

Although it is true that over half of all cases to be intubated in childhood can effectively be con trolled by gastro-duodenal intuba tion using a Levin tube or in in fancy even a small catheter, yet there remains a large percentage of cases, usually very ill children, in whom the tube must be passed far down the gastro-intestinal tract before good results are obtainable. Since the simplified intestinal tube can be passed through the nose so easily, it would seem most advantageous to routinely use it in all cases requiring intubation If gastric decompression alone is desired, fastening the tube to the side of the face with adhesive with the letter P' at the nose will effectively decompress the stomach On the other hand, if intestinal intubation is desired let the tube move on downward In this way the surgeon has all the advantages of a simple gastric tube with none of its disadvantages and if desired can readily pass the tube into the small bowel The size of the nostril of the average two to three year old child will very readily admit a 12 Fr simplified intestinal decompression tube

Constant attention must be given to the operation of the source of the negative pressure suction to be certain that the suction is continuous This is particularly important in children



Figure 127



Figure 128

Figure 127 Autopsy specimen of three month fetus. Note the outlet of the stomach Weighted tubes pass readily through because of absence of angulation.

Figure 128. Stomach and intestines removed from body Note that in infants that the pylorus is almost the apex of the stomach funnel. (*From* Bouslog, J S. Radiology *39* 252, 1942)

whose constant movement and often lack of comprehension of what is being accomplished may disrupt the hook up particularly if the Wangensteen bottle method is used

The intake and output must be carefully watched in children and measures taken to replace all water and electrolyte lost. This is much more important in children than in adults because of the rapidity with which these small patients show the ill effects of water and electrolyte disturbances Sufficient water and electrolytes must be given parenterally to insure an adequate urinary output with a urine of normal specific gravity The amount given must vary with the age of the child and the amount of fluid withdrawn by suction. Each case must be judged on its own merits In any case give at least five hundred c.c. more fluids per day than is suctioned out.

In discussing the shortcomings of suction as applied to the

The Permeability Q (in 10^{-8} cm^2 sec.$^{-1}$ atmos.$^{-1}$) and the Diffusivity D (in 10^{-7} cm^2 sec.$^{-1}$) of Gas in Various Elastomers

	H_2			O_2			N_2			CO_2			CH_4		He
t in °C	Q	$D=\frac{d^2}{6\theta}$	$D=\frac{Q}{k}$	Q	$D=\frac{d^2}{6\theta}$	$D=\frac{Q}{k}$	Q	$D=\frac{d^2}{6\theta}$	$D=\frac{Q}{k}$	Q	$D=\frac{d^2}{6\theta}$	$D=\frac{Q}{k}$	Q	$D=\frac{Q}{k}$	Q
Natural rubber															
17°	33	79	76	12	12.3	13	4.1	8.0	8.3	72	8.7	7.1	13.3		10.5
27°	39	105	100	19	17.5	18	6.6	11.5	12.6	103	10.5	11	22	8.8	22
37°	54.5	140	140	24.5	27	28	11.0	20	21	143	17	18.5	38		33
47°	—	195	190	39	38	37	16	23	29	193	23	28	50	21	41
50°	97	250	230	43.5	40	49	22.5	37	40	250	32	34	64		
Buna-S															
17°	22.5	80		9.0	8.6		3.0	7.2		71	6.8		10.5		13
27°	30 8	100	88	13	14	14	4.3	10	10	94	10	11	16		17.3
37°	41	135		20	20		7.3	14.6		130	15.5		25		25
47°	50.5	163	160	27.5	23	30	11.5	21	23	163	22	24	33		33
50°	74	200		34.5	34		14.6	23		185	29		43		43
Perbunan															
17°	7.8	31		2 0	2.4		0.50	1.43		18	1.0		1.3		5.5
27°	11.6	42	41	3.3	3.6	4.0	0.80	2 2	2.5	23	1.7	1.8	2.4		8.7
37°	17.8	64		5.3	6.3		1.45	4.1		37	.1		4.7		12.5
47°	25.5	86	82	7.7	9.1	8.6	2.5	6.2	6.2	53	4.7	5.3	7.0		16.8
50°	31.5	110		10.5	13		3.7	8.0		86	7.0		10.1		21
Neoprene-G															
17°	6.3	29		1.73	2.8		0.83	1.83		12.4	1.3		1.4		
27°	10.3	35	38	3.0	3.3	4 0	0.80	2.4	2.8	19.8	2.2	2.4	2.3		
37°	16	56		5.1	6.3		1.56	4.4		31	4.3		4.8		
47°	23	74	72	7.7	10.0	10.0	2.35	7.3	6.7	43.5	6.8	6.8	7.3		
50°	28.5	94		10.1	13		3.35	9.4		60.5	8.1		8.8		
Oppanol-B-200															
17°	3 0	10		0.54	0.80		0.11	0.37		2.3	0.33		0.2		3.8
27°	4.9	16	14	0.90	0.78	0.84	0.22	0 43	0.42	3.3	0.54	0.85	0.46		5.8
37°	8.3	21		1.8	1.35		0.44	0.84		6.6	1.06		1.1		8.5
47°	13	31	30	2 8	2 4	2.8	0.78	1.5	1.4	10.0	1.8	1.8	1.9		12
50°	16.5	38		3.7	3.4		1.18	2.1		14	2.5		2.0		16.5
Butadiene rubber															
17°	23	75		10.1	11		3.4	8.1		80	7.8				
27°	33	96		14.5	15		4.9	11		108	10.5				
37°	46	125		21	22		7.3	16		140	16				
47°	60	150		25	20		11	22		175	23				
50°	77	180		35	37		14.5	29		200	25				
Methyl rubber															
17°	9.6	57		0.53	0.95		0.30	0.46		3 0	0.56		—		8.1
27°	13	30		1.6	1.4		0.36	0.79		5.7	0.83		0.80		11
37°	20	61		3.1	2.5		0.70	1.7		10.8	1.3		1.48		16
47°	29	80		6 0	4.1		1.3	2.8		17	3 2		2.7		22
50°	38	105		7.3	6.1		2.2	4.1		26	3 6		4 4		27
Mipolam-MP															
17°	2.8	18		0 41	0 90					2.3	0.53				
27°	4 4	23		0.70	1.3		0.2			4 0	0.44				
37°	7.3	28		1 4	2.4		0 4			7 6	0.82				
47°	10.6	38		2 1	3.8		0.7			11.6	1 4				
50°	14	60		3.2	5.3					16	1.9				
Thiokol-B															
17°	0 71	7.8		0.11						1.3	0.42				
27°	1 2	10.5		0.22						2 4	0.81				
37°	2.2	18		0.47						4.8	1.7				
47°	3 1	25		0.85						7.3	2.8				
50°	4.8	33		1.3						11 0	4.0				

Figure 129 Chart taken from van Amerongen showing the permeability of the different kinds of rubber to various gases at different temperatures. Note that Neoprene-G of which balloons of the Cantor tube are now being made is far less permeable to all gases than is the natural rubber (latex)

"Effect of intestinal gases upon balloons of intestinal decompression tubes."
E. R. Phelps Ph.D
M O Cantor M D., M.S., F.A.C.S
R. H Ealing M.S.

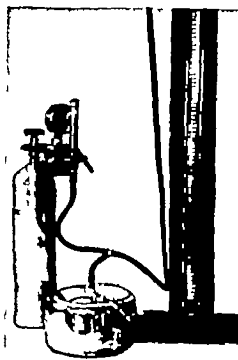


Figure 130



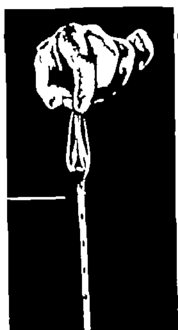
Figure 131

Figure 130 Apparatus for testing the balloons. p" pressure chamber into which *the balloons are placed. "m" manometer measuring the gas pressure* within the gas chamber

Figure 131 Note that the balloon containing the mercury also contains a well defined amount of gas. Note position of balloon at the duodeno-jejunal flexure.



Figure 132. Note that now the balloon is at the ileo-caecal valve. Note also that the amount of gas within the balloon has diminished.



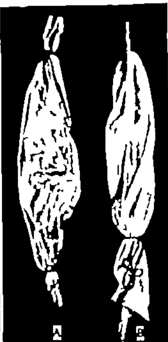


Figure 133 Figure 134

Figure 133 Note that the tie is applied to the shaft of the tube over the point of attachment of the balloon The tie is tied tight enough to trap the mercury but air can get in and out. To accomplish this insert a stylet from a 22 gauge needle through the last hole into the balloon and tie over it. After tying off the tube remove the stylet. This will leave a small opening through which gas can come out, but no mercury

Figure 134 Balloons of Harris tubes. "A" balloon containing mercury "B" no mercury in this balloon. Note that both balloons contain gas.



Figure 135 Balloon of Miller Abbott tube. Note gas in balloon

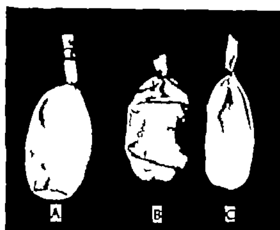


Figure 136. Balloons of Cantor tube. "A" empty balloon. "B" balloon containing mercury. This took up little gas. "C" balloon containing glass beads. This balloon took up seventeen c.c. of gas.



Figure 137. Balloon of Harris tube containing glass beads. Note large amount of gas in the balloon. This gas was then removed and the tube retied. This perfused balloon when subjected to (55 mm.) pressure of carbon dioxide then took up an equal amount of carbon dioxide.

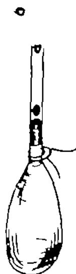


Figure 138. Sketch of balloon attached to tube. Note double loop tie being applied to the point of attachment of balloon to tube.



Figure 139
Figure 141

Figure 140
Figure 142





Figure 144

Figure 143
Figure 145

Figure 139 Three month old boy Oblique view Note the simplicity of infant's stomach and the position of the first limb of the duodenum. A weighted labile tube head could readily pass through the pylorus with child sitting up

Figure 140. Three month old boy Note that there is no downpouching of the greater curvature and that the pylorus and the greater curvature lie on approximately the same level. For this reason, special positioning to secure duodenal intubation is not needed. The activity of the child alone would be sufficient to induce a successful intubation.

Figure 141 Four year old boy Note that the pylorus and the greater curvature of the stomach lie at the same transverse plane.

Figure 142. Five year old boy Note the level of the greater curvature and the pylorus. Note also that the first limb of the duodenum is relatively on about the same horizontal plane as the stomach. This renders intubation fairly simple.

Figure 143 Five year old boy Note that there is no appreciable downpouching of the greater curvature and the position of the first limb of the duodenum. With the child sitting up a freely motile tube head need not run uphill to successfully intubate the duodenum. The course of the tube head from the stomach to the second limb of the duodenum is here seen to be almost directly downhill with child sitting or erect.

Figure 144 Eight year old girl. Note that the level of the pylorus and the greater curvature of the stomach is almost the same.

Figure 145 Nine year old girl. Note the relative simplicity of the child's stomach. There is no downpouching of the greater curvature. The first limb of the duodenum and the stomach generally are of the "steer-horn" type rather than of the "J type" when described in terms of the adult stomach.

gastro-intestinal tract, Wangensteen has pointed out that during the interval during which intubation is being carried out and one waits for the obstructing mechanism to relent, that the bowel above the obstruction cannot be used as a nutritive tube This is especially true in those instances in which gastro-duodenal intubation is carried on When the bowel is drained by the passage of a long intestinal decompression tube with the head of the tube down to the point of obstruction, the small bowel above the point of obstruction may be utilized as a nutritive tube This point is particularly important in children in whom impairment of nutrition rapidly produces deleterious effects Since by using a long tube, most of the absorptive area lies above the point from which suction is exerted, nutrition can be maintained by oral feeding

The following group of figures illustrate stomachs in infants ranging from five days old to nine years. The simplicity of the infant stomach makes intubation comparatively easy without special positioning of the patient.



Figure 146



Figure 147

Figure 146. Five day old child. Death due to mesenteric thrombosis. Note the tremendously distended stomach which does not pouch downward but assumes an oblique position so that the first limb of the duodenum and the pylorus become the apex of the stomach much like the outlet of a funnel. Note that the first limb of the duodenum and the stomach lie on approximately the same horizontal plane

Figure 147 Five weeks old child. Note greatly distended stomach. Note the position of the first limb of the duodenum. The direction of a tube passed from the stomach to the duodenum would be almost directly downhill. Even with this markedly distended stomach there is no downpouching of the greater curvature as found in the adult. Because of this there is no angulation between stomach and duodenum. Hence no positioning is needed for intubation

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CHAPTER XVII

EFFECT OF INTESTINAL GASES UPON BALLOONS OF INTESTINAL DECOMPRESSION TUBES

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THAT rubber membranes were permeable to gases has been known to physicists for over one hundred years This fact was first noted in 1831 when Mitchell published a paper[223] discussing the permeability of rubber membranes to gases He noted at that time that the rate of permeability varies with different gases used Concomitant with the tremendous strides made in the development of synthetic rubbers it was noted that the different rubbers behaved differently to each specific gas That is it was soon noted that the permeability of each type of synthetic rubber differed for each kind of gas Extensive studies were carried on throughout the world with the final result that the permeability of each type of rubber has been charted for each specific gas under many conditions of temperature and pressure

As a result of studies by numerous workers[224,225,226] it has been demonstrated that the behavior of gases in rubber is similar to that of gases in organic liquids As a result of this observation rubber may be considered as an organic liquid of high molecular weight Thus when a gas is brought into contact with a rubber membrane it goes into solution in the rubber on the one side of

the membrane and then emerges on the other side by evaporation This process is known as permeation of the gas through the rubber membrane It is quite important to note that this process of permeation consists of two separate and distinct factors On the one hand is the solubility of the gas into the rubber and on the other hand the diffusion of the gas through the rubber and its evaporation on the other side of the membrane. In studying this phenomenon it was soon noted that the permeability of any specific gas through a rubber membrane is independent of the presence of any alien gas on the other side of the membrane In addition, the law of diffusion of gases would apply to the passage of the gas through the rubber membrane That is, that the specific gas tends to pass from an area of increased pressure into one of decreased pressure for that specific gas until equal pressures for that gas were obtained on both sides of the rubber membrane In addition, the presence of other gases on the one side of the rubber membrane has no effect upon the permeability of the rubber to any one specific gas

The results of these extensive researches were finally formulated ihto two laws *Henry's Law* which postulates that the gas first dissolves in the rubber to a degree which is proportional to the pressure, and *Frick's Law* which postulates that the gas dissolved in the rubber diffuses in the rubber toward that part of the rubber where the gas is present in a lower concentration finally the gas evaporates out of the rubber

One of the striking facts which was noted during these studies was the fact, noted by some and disputed by others that the solubility of hydrogen and nitrogen in rubber like substances increases as the temperature increases This suggests that heat is required to dissolve the gas in the rubber This group believe that the activation energy of the diffusion is required to separate the loosely arranged rubber molecules for the displacement of the gas molecules A linear relationship has been noted by most investigators between the logarithm of the solubilities of different gases in natural rubber and their critical temperatures so that the higher the critical temperature of the gas, the better it dissolves Barrer [229] on the other hand in his experiments with nitrogen and hydrogen has noted that the solubility of these gases

decreased as the temperature increased Van Amerongen,[20] however in summarizing the research to date and his own observations was led to the inevitable conclusion that the solubility of a gas *does increase with an increase in the temperature* Carbon dioxide, however, being a highly soluble gas exhibits a decrease in solubility in rubber an organic liquid as the temperature rises

The permeability of rubber substances to gas being related to the solubility and the rate of diffusion of the gases in these materials it was inevitable that the specific values for each kind of gas and each type of rubber was determined (see Figure 129) The permeability of the rubber membranes was determined manometrically and the diffusivity was determined from the time lag of the permeation The solubility of the gas was computed from the permeability and the diffusivity In this way the solubility could readily be determined The differences in the permeability of different rubber membranes to a given gas are caused chiefly by differences in the rate of diffusion and only in a minor extent to differences in solubility The differences in the permeability of the same rubber membrane to different gases, however, is caused not only by differences in the rate of diffusion but also by the differences in solubility

As a result of all these studies the quantity of a permeating gas can readily be found by the following equation

$$q = D\,h\,A\,\frac{(p1 - p2)}{d}\,t$$

In this equation the following values are known or can readily be found

q — the quantity of gas permeating through the rubber membrane

D — the diffusivity of each specific gas through each specific type or rubber membrane This value has been determined for all types of rubber and all types of gas (see Figure 129

h — the solubility of the gas in the specific type of rubber membrane This value has been determined for all types of rubber and all types of gases which might be found in the gastro-intestinal tract

A — the area of the membrane In the case of the balloons of intestinal decompression tubes, this value can readily be found.

$p1 - p2$ — is the pressure of the specific gas on each side of the rubber membrane

d — is the thickness of the rubber membrane. This value in the case of the balloons of the intestinal decompression tube is known.

t — is the time for which the rubber membrane is exposed to the gas

Using this formula and knowing the fixed values for D, k, A, $p1$ $p2$ D, and t it becomes a relatively easy matter to determine the quantity of gas which will permeate through any type of rubber membrane at a definite period of time. Although this can be readily determined in vitro, the same does not apply with the same degree of exactitude in vivo While we know the specific diffusivity of any given gas through any given type of rubber membrane as well as the solubility of each specific gas in each type of rubber at many temperatures, and although we know the area (A) of the rubber balloon of the intestinal decompression tube, and we also know the thickness of each type of rubber ballon (d) and the time (t) during which the balloon of the intestinal tubes are exposed to the intestinal gases, we do *not know however exactly what the pressure of the intestinal* gases is in any specific case Numerous studies have been made to determine the intra intestinal pressure, both in the normal as well as in the obstructed bowel of dogs and also humans As a result of these studies [331, 332, 333] variations of intra intestinal pressure in cases of bowel obstruction have been found to range from four to nineteen centimeters of water (2 9 mm mercury to 13 9 mm mercury) in the ileum of dogs In humans, intra intestinal pressures in the ileum ranging from four to fourteen centimeters of water (2 9 mm. mercury to 10 2 mm of mercury) have been reported with a rise to thirty centimeters of water (22 mm of mercury) with peristaltic activity In the colon however, intra intestinal pressures ranging from twelve to fifty two centimeters of water (8 8 mm of mercury to 38 2 mm of mercury) were

noted in humans, when colostomy was performed Wangensteen reported the usual intra intestinal pressure in the colon as ranging between ten and twenty five centimeters of water (7 3 mm of mercury to 18 mm of mercury)

From the preceding discussion, it is evident that although we do not know the exact intra intestinal pressure in any case of intestinal distention nevertheless the variation or extent of the range between the high and the low values is not sufficiently great as to radically interfere with the computation of the quantity of gas which permeates into the lumen of the intestinal decompression tube balloon in any give period of time A very high degree of exactitude is not needed clinically but merely a close value is sufficient.

The kinds of gas found in the gastro-intestinal tract in cases of intestinal distention has been the subject of much investigation As a result not only do we know what gases may be expected to be found in the gastro-intestinal tract in cases of intestinal distention but also the concentration of each type of gas is fairly well known within reasonable limits It has been well established that practically all the gas found in the gastro-intestinal tract in early post-operative intestinal distention is due to swallowed air, after the anaesthetic agent has been dissipated if general anaesthesia was used That being the case, we know almost the exact composition of the gas found in such cases In cases of small bowel obstruction however numerous studies have been carried out to determine the composition of the intestinal gases found and their percentages From these studies by Wangensteen[224] Hibbard,[225] Ringsted and Andersen, Fine *et al*,[226] and many other workers the composition of intestinal gases in cases of small bowel obstruction is seen to consist of the following

Nitrogen — 70 to 80% There was some variation in this value depending upon the site of the obstruction Obstructions of the colon generally gave higher values than obstructions of the small bowel

Oxygen — 1 to 10% Here too there was a marked variation in the values obtained depending upon the site of the obstruction Lower values were found with lesions of the colon although some high values were also found in this type of case

A — the area of the membrane. In the case of the balloons of intestinal decompression tubes, this value can readily be found.

p1 — *p2* — is the pressure of the specific gas on each side of the rubber membrane.

d — is the thickness of the rubber membrane. This value in the case of the balloons of the intestinal decompression tube is known.

t — is the time for which the rubber membrane is exposed to the gas.

Using this formula and knowing the fixed values for *D*, *h*, *A*, *p1*, *p2*, *D*, and *t*, it becomes a relatively easy matter to determine the quantity of gas which will permeate through any type of rubber membrane at a definite period of time. Although this can be readily determined in vitro, the same does not apply with the same degree of exactitude in vivo. While we know the specific diffusivity of any given gas through any given type of rubber membrane, as well as the solubility of each specific gas in each type of rubber at many temperatures, and although we know the area (*A*) of the rubber balloon of the intestinal decompression tube, and we also know the thickness of each type of rubber ballon (*d*), and the time (*t*) during which the balloon of the intestinal tubes are exposed to the intestinal gases, we do not know, however, exactly what the pressure of the intestinal gases is in any specific case. Numerous studies have been made to determine the intra intestinal pressure both in the normal as well as in the obstructed bowel of dogs and also humans. As a result of these studies[221, 222, 223] variations of intra intestinal pressure in cases of bowel obstruction have been found to range from four to nineteen centimeters of water (2.9 mm. mercury to 13.9 mm. mercury) in the ileum of dogs. In humans, intra intestinal pressures in the ileum ranging from four to fourteen centimeters of water (2.9 mm. mercury to 10.2 mm. of mercury) have been reported with a rise to thirty centimeters of water (22 mm. of mercury) with peristaltic activity. In the colon, however, intra intestinal pressures ranging from twelve to fifty two centimeters of water (8.8 mm. of mercury to 38.2 mm. of mercury) were

noted, in humans, when colostomy was performed Wangensteen reported the usual intra intestinal pressure in the colon as ranging between ten and twenty five centimeters of water (7 3 mm of mercury to 18 mm of mercury)

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Nitrogen — 70 to 80% There was some variation in this value depending upon the site of the obstruction Obstructions of the colon generally gave higher values than obstructions of the small bowel

Oxygen — 1 to 10% Here too there was a marked variation in the values obtained depending upon the site of the obstruction Lower values were found with lesions of the colon although some high values were also found in this type of case

Carbon dioxide — 4 to 18% There was a marked variability in the range in this gas found in cases of bowel obstruction. Most of the values reported by Wangensteen were well under 10% Hibbard noted that the carbon dioxide increased with the duration of the bowel obstruction It is apparent that this gas is present in cases of bowel obstruction in much higher concentrations than found in atmospheric air From this, it must also be apparent that because of its high degree of permeability and high concentration in cases of bowel obstruction, that carbon dioxide might constitute a troublesome factor in any case being intubated for any length of time

Hydrogen — 1 to 6% This gas being present in low concentration would not be expected to create much of a problem for the intubator

Hydrogen sulphide — 2 to 12% is found in much higher concentrations than in atmospheric air In addition, this gas tends to increase with the duration of the intestinal distention

Since all the factors noted in our formula for permeability are known and since we know the types and concentrations of gases in cases of bowel obstruction we are now in a position to further investigate this problem

Of all the gases found in the gastro-intestinal tract in cases of *intestinal distention the carbon dioxide* is apt to be most troublesome for the intubator The reason for this is that this gas is highly permeable to the natural rubber found in the balloons of most of the long intestinal decompression tubes in use today In addition the concentration of this gas within the bowel is greater than its concentration within the balloon of the intestinal decompression tube It should be quite evident that although we express all the atmospheric air from the balloon of the intestinal decompression tube before inserting it, nevertheless some atmospheric air remains within the balloon From the preceding discussion following the law of diffusion of gases one would expect the carbon dioxide to diffuse through the wall of the balloon into its lumen distending it until the pressure of the carbon dioxide within the balloon equalled its pressure around it i e. in the intestinal tract The same mechanism would of course apply to the other gases found in the gastro-intestinal tract.

The importance of these studies is quite apparent when one realizes that an increase in the amount of gas within the balloon of the long intestinal decompression tube, where no gas is supposed to be, results in a bulging of the bowel wall around it. If the patient is partially obstructed a ball valve type of obstruction results from the presence of a distended balloon pushing against the point of obstruction If the patient is suffering from stomal edema at the point of anastomosis, then the presence of such a distended balloon would completely obstruct the bowel On the other hand, when an attempt is made at the removal of a tube with a distended balloon a tear in the anastomosis is apt to occur if the tube head is distal to the anastomotic site In some cases the balloon may become so tremendously distended as to tear the bowel. Cases in which the metal tip of a Miller Abbott tube has perforated the bowel[237] at the point of obstruction have been reported These accidents, uncommon to be sure, have been noted with long intestinal decompression tubes A knot formation in the Miller Abbott tube proximal to the balloon may set the stage for the development of a markedly distended balloon with gas (see Figure 112)

As a result of our studies upon the effect of intestinal gases upon the balloons of intestinal decompression tubes, we have succeeded in completely eliminating this complication to intestinal intubation The construction of the Cantor tube lent itself very well to simply and easily preventing this complication whereas the use of the Miller Abbott tube which depended upon an air filled balloon alone could not be so treated as to prevent the introduction of gas into the balloon when the channel for inflation becomes obstructed In the use of the Harris tube using mercury prevention of the intake of gas by the balloon is possible as we shall demonstrate in our experimental studies

EXPERIMENTAL STUDIES

The gas used in our studies was carbon dioxide because as noted it is the most diffusible through rubber membranes and because its concentration within the bowel increases with the duration of the bowel obstruction We tested this gas with all the commonly used types of intestinal decompression tubes The

apparatus used to test the effect of the gas upon the balloon intestinal decompression tubes was a very simple yet effective In Figure 130, you note the gas cylinder with gauge capabl permitting the gas to enter our pressure chamber (*p*) at a def rate to compensate for the loss of gas through the rubber nections and the incomplete gas-tightness of our equipment. pressure chamber (*p*) is then connected to a mercury manom (*m*) which measures the pressure within the chamber corre to the millimeter of mercury After much experimentation, were able to set our flow of gas into the chamber at such a as to keep the pressure of the gas in the pressure chamber stant within fairly narrow limits In this way, we were abl subject our tube heads to varying degrees of pressure at r temperature In order to insure that the chamber was filled pure gas being tested at the beginning of each experiment would place the tube heads within the chamber place the lid u the pressure chamber then, using the blade of a thin knife un the lid we would turn on a full flow of the pure gas into chamber at high pressure If this is done for several minu the air present in the chamber is forced out through the ch made by the blade of the penknife At the end of several minu the gas pressure going into the pressure chamber is reduced the knife blade is quickly removed Our pressure chamber contains a pure gas from the cylinder We now set the flow of into the chamber at such a rate as to keep the pressure wit the chamber at any desired level

The volume of the gas within the balloons was determi by the water displacement method. By immersing our ballo into a measured amount of water in a measuring flask of 250 capacity we were able to rapidly and simply determine the amo of gas within the balloon The value obtained for each ballo before being put into the pressure chamber (with balloon emp when subtracted from the value obtained after removal of balloon from the pressure chamber would be the amount of taken up by the balloon in cubic centimeters

In using all three types of intestinal decompression tu commonly used today we noted first that the balloons were of latex rubber so that the diffusivity of a specific gas carb

dioxide, through this specific rubber should be the same und the same conditions However, on measuring the thickness the walls of the balloons used with the Miller Abbott and Har tubes, we found them to be 0 06 mm thick The thickness the wall of the Cantor tube ranged from 0 24 mm in its mid to 0 40 at the base and neck In addition, the Cantor tube a the Miller Abbott tube both present balloons about two and o half inches long with the diameter of the Miller Abbott tu somewhat greater than that of the Cantor tube The balloon the Harris tube, however, is six inches long, and of the sar diameter Referring back to the formula quoted by van Amerc gen for the quantity of gas permeating through a rubber me brane we find

$$q = D\,h\,A\,\frac{(p1 - p2)\,t}{d}$$

Since (d) represents the thickness of the rubber membra it would be evident that the balloons of the Miller Abbott a Harris tubes would be expected to take up more gas than t balloon of the Cantor tube which is almost four times as thic Moreover the Harris tube having a balloon six inches long wou be expected to take up far more gas than any other tube in u today, because the value for (A) which is the area of the rubb membrane is more than double that of either the Miller Abb or Cantor tubes

With these preliminary observations in mind, we proceed to test all the tube heads under varying conditions to check t applicability of the formula quoted by van Amerongen to clini medicine

EXPERIMENT I

To note the effects of high pressures upon the balloons intestinal tubes, we placed the sealed empty balloons into t chamber and raised the pressure of the carbon dioxide to 180 m of mercury for twenty four hours At the end of this period time we found ten c.c. of gas in the balloons This rapid c servation informed us that gas does enter the balloons We n proceeded systematically to study these balloons under varyi conditions

EXPERIMENT II

For this experiment, three balloons from Cantor tubes were used. The balloons were used without being attached to the tubes in order to determine the effect of the carbon dioxide upon the balloons by themselves without tubal attachment. Two of the balloons were tied off at the neck using a silk tie and one balloon was cemented closed at its mouth. In this fashion we could determine whether the presence of the silk tie in any way influenced the permeability of the balloons. It was thought that the tie might injure the rubber so as to increase its permeability at that point. In this experiment a pressure of 37 mm. of mercury was maintained in an atmosphere of carbon dioxide for twenty four hours. At the end of that period of time it was found that the cemented balloon contained seven c.c. of carbon dioxide whereas the tied off balloons contained nine c.c. for one and three c.c. for the other. We examined the tied off balloons carefully to determine the reason for the variation in amount of gas. We concluded from our examination that the tightness of the tie was the important factor. In that balloon in which the tie had been looser the highly diffusible carbon dioxide readily escaped whereas in the very tightly tied balloon it remained trapped. This at once suggested a preventative to the development of gas within the balloon of the Cantor tube when clinically used.

The balloons containing the carbon dioxide were then permitted to lie exposed to the atmosphere to determine how rapidly the carbon dioxide would diffuse out since the concentration of carbon dioxide in the atmosphere is much lower than that now present in the balloon. At the end of forty five minutes, we found that the cemented balloon had lost two c.c. of the gas, the tightly tied balloon had lost three c.c. of its gas, whereas the not so tightly tied balloon had lost all of its gas.

The same balloons were permitted to lie exposed to the atmosphere overnight and were re-checked in the morning. At this time no gas was found in any of the balloons.

The practical implications of the observations are apparent. If for any reason the balloon of the long intestinal decompression tube should become torn off and gas remain trapped within the

balloon, then by decompressing the bowel the gas would rapidly leave the balloon so that the mercury-balloon could move down the gastro-intestinal tract and so be excreted. Figures 131 and 132 present an unusal case in which this accident occurred. After being in the patient for twelve days the balloon was torn from the tube during the removal of the intubation tube. It can readily be seen from Figure 131 that a fairly definite amount of gas is present in the balloon, and the balloon can be identified as being at or just beyond, the duodeno-jejunal flexure. Figure 132 was taken from a roentgenogram four days after Figure 131. Note, now, the marked decrease in the amount of gas present in the balloon and note also that the balloon containing the mercury has moved down to the ilio-caecal valve.

To prevent any possible chance of this happening again, we advise that the tie in the Cantor tube be placed on the shaft of the tube just above its distal end at the point at which the balloon is cemented to the tube. By so doing it would be almost impossible to tear off the balloon, and if it did occur the gas and mercury would readily escape without harm to the patient.

EXPERIMENT III

In this experiment ten balloons were used to determine the effect of 15 mm. of mercury pressure in an atmosphere of carbon dioxide for four days. Both new and used balloons were utilized in this experiment. This study would demonstrate any changes in permeability that the balloons might undergo by virtue of having been soaked in the intestinal contents of the patient for varying lengths of time as well as the effect of the mercury upon the rubber of the balloons.

Balloon 1. New balloon containing mercury for five weeks. This balloon was tied off with five c.c. of mercury for five weeks. At the end of this period of time, the rubber of the balloon was discolored black. There was no vaporization of the mercury in the balloon since the volume of this balloon and the volume of a new balloon containing the same amount of mercury was exactly the same. At the end of the four days at 15 mm. of mercury carbon dioxide pressure, this balloon took up 7 c.c. of carbon dioxide.

Balloon 2 Balloon which had been in the patient soaking in intestinal secretions for twenty four hours This balloon was then dried and sealed empty in an envelope for thirteen more days before being used in this experiment Care was taken to tie off the neck of the balloon tightly and to separate the walls of the balloon so they would not stick. This balloon took up twenty three c.c of carbon dioxide in the four day period at 15 mm mercury pressure

Balloon 3 Balloon which had been in the patient for five days soaking in intestinal secretions The balloon was then dried and kept in a sealed envelope for thirteen more days before being used in this experiment. This balloon took up only four c.c in four days at 15 mm mercury It is apparent from this that soaking the balloon in the intestinal secretion does not increase its permeability, but that some other explanation must be sought for the result in balloon 3 We felt that the probable answer was that in balloon 3 the walls of the balloon were squeezed together in an effort to express all the atmospheric air with the result that they tended to stick together so that the two sides of the balloon acted as one membrane with no cavity for the carbon dioxide to remain in This point will be again checked in Experiment IV

Balloon 4 This balloon was in the patient for ten days soaking in the intestinal secretion, and the mercury remained in the balloon for a total of thirty seven days. This balloon took up 15 c c of carbon dioxide in the four days at 15 mm mercury pressure

Balloon 5 This balloon was in the patient for five days, and in a sealed envelope for thirteen more days No mercury used in this balloon during the test This balloon took up four c.c of carbon dioxide

Balloon 6 The balloon from a Miller Abbott tube was tied off at both ends without a tube passing through it in an effort to see whether the empty balloon itself would take up any carbon dioxide We found no carbon [illegible] in this balloon at the end of four days at 15 mm me[illegible] sure The walls of the balloon were close cont[illegible] other because of their thinness. [illegible] on arose [illegible] this ball[illegible] so highly [illegible] it coul[illegible] carb[illegible] or

whether as in balloon 3 the walls of the balloon being in contact with each other there was no space for the gas to pass into We therefore investigated this point in Experiment IV

Balloon 7 An empty latex balloon from a Harris tube was then tied off at each end This was a new balloon This balloon did not take up any carbon dioxide Again the question arose as to whether the balloon was so highly permeable that it could not hold the carbon dioxide or whether the walls of the balloon in contact with each other prevented the gas from entering This too is to be studied in Experiment IV

Balloon 8 This balloon was attached to a two inch length of tube Five c c of mercury was placed in the balloon and the balloon sealed by doubly tying tightly at the point at which the balloon was cemented on to the tube (Cantor) In this way the tube was tied off so tightly that neither air nor mercury could get in or out This balloon took up 18 c c of carbon dioxide in the four day period at 15 mm of mercury pressure From this it is evident that the mercury by separating the walls of the balloon creates a space into which the carbon dioxide could diffuse

Balloon 9 This balloon was attached to a two inch length of tube and 5 c.c of mercury placed in the balloon The tube was tied off at the same point as in balloon 8 but the tie was tied only tight enough to trap the mercury but not tightly enough to seal in the air We could blow air into the balloon and squeeze it out of the balloon but the mercury could not escape Now squeezing all the air out of this tied off balloon and placing it into the same chamber for the same period of time as balloon 8 we found that *this balloon took up only 6 c c of carbon dioxide* Furthermore when this balloon was immersed in our measuring flask of water to determine the volume of carbon dioxide which it took up the gas rapidly bubbled out of the balloon due to the slight pressure of the column of water around it.

Balloon 10 This balloon was attached to a two inch length of tube. Five c c of mercury was placed in the balloon The tube was then tied off at the same point as balloons 8 and 9 (at the distal end of the tube just above its terminal end and at the point at which the balloon was cemented on) The double loop tie was again tied tightly enough to seal in the mercury but the air could readily get in and out of the balloon. This balloon was

found to take up 8 c c of carbon dioxide at the end of four days at 15 mm mercury pressure This balloon also rapidly lost its carbon dioxide by the slight water pressure incident to measuring its gas volume

Conclusions from This Experiment

It is evident from this experiment that the length of time that the balloon is permitted to soak in gastro-intestinal contents does not affect its permeability, nor does the length of time that the mercury is permitted to remain in contact with the rubber appear to affect its permeability to carbon dioxide. It also suggests that the walls of the balloon must be separated before the balloon will take up any carbon dioxide, although this point will be checked in Experiment IV The most important observation in this experiment is the observation that when the tie is applied loosely so that the mercury is trapped but the air can get in and out of the balloon that a markedly reduced volume of carbon dioxide is taken up and this small volume is rapidly lost with the slightest pressure Clinically a practical application of this point would be the application of the tie in the Cantor tube to the point just above the terminal end of the tube at which the balloon is cemented on If this tie is tied tightly enough to trap the mercury but not completely occlude the tube so that air can get in and out not only will such a tube take up a very small amount of gas if exposed to such high pressure, but the contraction of the bowel wall upon the balloon and the pressure of intestinal secretions would promptly empty the balloon of all gas In this fashion by applying one tie in this way, it would be impossible for any gas to remain trapped in the balloon of the Cantor tube. This same point might be utilized in the other types of tubes that depend upon mercury to carry the tube head downward. It could not be used in the Miller Abbott tube in which air alone is used to fill the balloon as these tube heads must be airtight In this type of tube, however the double lumen which permits aspiration of the distended balloon would furnish an adequate safety valve In the event that the tube became knotted however the gas would be trapped and the balloon would then distend markedly as seen in Figure 112

EXPERIMENT IV

In order to determine whether the latex rubber of the Miller Abbott and Harris tubes with a thickness of 0 06 mm was so highly permeable to carbon dioxide that it could not retain it or whether the walls of the balloon in Experiment III were adherent and thus prevented the intake of carbon dioxide the following experiment was performed

The balloons were fastened upon rubber tubes exactly like the tube appears for use clinically All the air was expressed from the balloons and then the tubes with the balloons attached were subjected to 34 mm of mercury pressure for forty-eight hours At the end of this period of time the following results were obtained

1 The Harris tube with mercury in the balloon took up twenty c.c. of carbon dioxide
2 The Harris tube with the balloon empty, took up twelve c.c of carbon dioxide
3 The Miller Abbott tube empty took up eight c c of carbon dioxide

This experiment shows rather conclusively that the carbon dioxide gas does diffuse through the balloons of the Miller Abbott and Harris tubes It also demonstrates that this occurs when the walls of the balloons are kept apart by the shaft of the tube which traverses the balloons. In addition, the presence of an inert substance such as mercury which further separates the walls of the balloons permits a greater amount of carbon dioxide to enter the balloons

We now subjected the balloons to one hundred mm of mercury pressure of carbon dioxide to determine whether any more gas would enter the balloons at that high pressure in a short period of time (twenty minutes) We found that the carbon dioxide did not enter the balloons in the twenty minute period even at that high pressure We must conclude from this that the carbon dioxide diffuses into the balloons at a rate such that no increase in the carbon dioxide could be noted at this pressure in the twenty minute period

EXPERIMENT V

The purpose of this experiment was to determine whether the mercury caused more carbon dioxide to enter the balloon because of some special effect within the balloon or whether it was merely the inert mass of mercury separating the walls of the balloon which resulted in the increased amount of gas intake as compared with the empty balloons

In this experiment we used eight balloons, and subjected them to a pressure of carbon dioxide that ranged from thirty to forty mm of mercury for forty-eight hours The following results were obtained

Balloon 1 Plain empty Cantor tube and balloon with all the air expressed from the balloon by rolling up the balloon tightly This resulted in a close co-aptation of the walls of the balloon. At the end of forty eight hours this balloon had taken up no carbon dioxide

Balloon 2 Plain empty Cantor tube and balloon treated the same as balloon 1 No gas was found in the balloon at the end of forty eight hours

Balloon 3 Glass beads in an amount equal to the volume of mercury used was placed in the balloon of the Cantor tube and subjected to the pressures of carbon dioxide as noted above. At the end of forty-eight hours eighteen c.c. of carbon dioxide was found in the balloon

Balloon 4 Glass beads in an amount equal to the volume of mercury was placed in the balloon of the Cantor tube as in balloon 3 At the end of forty-eight hours seventeen c.c. of carbon dioxide was found in the balloon

Balloon 5 Mercury was placed in the balloon of the Cantor tube in an amount equal to the beads and the same conditions used At the end of forty-eight hours, two c c. of carbon dioxide was found in the balloon.

Balloon 6 Cantor tube and mercury in the balloon as in balloon 5 At the end of forty-eight hours two c.c. of carbon dioxide was found in the balloon

Balloon 7 Harris tube without mercury subjected to the same conditions At the end of forty-eight hours this balloon was

found to contain sixty six c c of carbon dioxide

Balloon 7a Harris tube with the balloon containing 5 c c of mercury was subjected to the above conditions At the end of forty-eight hours this balloon was found to contain thirty two c c of carbon dioxide

Balloon 8 Miller Abbott tube with empty balloon was subjected to the same conditions At the end of forty-eight hours the balloon was found to contain ten c c of carbon dioxide

The observations in this experiment followed the formula of van Amerongen that the amount of gas that permeates through a rubber membrane is directly influenced by the area of the balloon Hence the balloons of the Harris tube took up far more gas than did the balloons of the Miller Abbott or Cantor tubes. Since the latter two balloons are one half the size of the balloon of the Harris tube this result was to be expected The experiment also showed that mercury as such did not increase the permeability of the balloons but that it acted merely as an inert mass keeping the walls of the balloons apart and thus creating a cavity for the carbon dioxide to permeate into The markedly greater amount of carbon dioxide that diffused into the balloons containing the glass beads as compared with the balloons containing the mercury is quite understandable when one considers that by the use of glass beads the walls of the balloon are much better separated and the small spaces between the surfaces of the beads does not permit the walls of the balloon to rest smoothly upon their surfaces It becomes evident that anything that will effectively separate the walls of the balloons will result in an increased intake of carbon dioxide Even with the Miller Abbott and Harris balloons empty the presence of the shaft of the tube passing through these balloons effectively creates a cavity for the intake and storage of carbon dioxide

EXPERIMENT VI

The purpose of this experiment was to determine whether perfusion thoroughly of the balloons with carbon dioxide until their walls were saturated with this gas would prevent the intake of carbon dioxide.

For this experiment eight balloons were employed These

alloons were subjected to ten mm of mercury pressure of carbon ioxide for forty-eight hours This pressure range is well within hat found clinically in cases of intestinal distention in humans The following results were obtained

Balloon 1 Harris tube with the balloon containing mercury *vas found to have taken up fifty c c. of carbon dioxide at the end* f forty-eight hours

Balloon 2 Miller Abbott tube was found to have taken up eventeen c.c. of carbon dioxide at the end of forty-eight hours

Balloon 3 Cantor tube containing glass beads in an amount qual to the amount of mercury used was found to contain eighteen .c. of carbon dioxide at the end of forty-eight hours

Balloon 4 Cantor tube with the balloon containing glass eads in an amount equal to the volume of mercury used At the nd of forty-eight hours this balloon had taken up seventeen c.c. f carbon dioxide

Balloon 5 Cantor tube with balloon containing five c.c. of ercury This balloon took up six c c of carbon dioxide at the nd of forty eight hours

Balloon 6 Cantor tube with the balloon containing five c.c. f mercury This balloon took up three c.c. of carbon dioxide at ie end of forty-eight hours

Balloon 7 *Cantor tube with the balloon empty* This balloon ad been perfused and then rolled up to express all the gas pre minary to being tied off This balloon took up three c.c. of rbon dioxide in forty-eight hours

Balloon 8 Cantor tube with balloon empty This balloon ad been perfused with carbon dioxide and then the gas evacuated y rolling up the balloon and tying off at its neck. This balloon as found to contain four c c. of carbon dioxide at the end of orty eight hours

The results of this experiment show rather conclusively that erfusing the balloons thoroughly with carbon dioxide so that the all of the balloon was thoroughly saturated with this gas, did ot prevent the permeation of the gas through the wall of the illoon into its lumen It has demonstrated that the only im ortant antecedent required for the passage of gas into the

balloons of intestinal tubes is the presence of any inert mass that would separate the walls of the balloon thus creating a cavity for gas to accumulate

CLINICAL APPLICATIONS OF EXPERIMENTAL DATA

As a result of our experimental studies we can state definitely that all balloons of long intestinal decompression tubes are permeable to intestinal gases in the fashion as noted by van Amerongen (see Figure 129) The permeability for each specific type of rubber membrane and each specific kind of gas has been determined with such exactitude that a formula has been set up Being reduced to a formula whose factors are known, the quantity of gas that diffused through a specific type of rubber balloon can readily be computed. Carbon dioxide is the gas most likely to diffuse into the balloons of intestinal decompression tubes because of its high degree of diffusibility and because of the markedly higher concentration of this gas within the bowel as compared with its concentration within the balloon Nitrogen and oxygen within the bowel do not vary widely from the concentration found within the balloon which is atmospheric air As a result, the permeation of these gases into the balloons of intestinal tubes would not be expected to be very rapid because the difference in pressures of these gases within the balloons and in the bowel is not too divergent Hydrogen sulphide which accumulates in the gastro-intestinal tract in a much higher concentration than is found within the balloon of intestinal decompression tubes is a gas which diffuses through the rubber membranes with such rapidity that it rarely constitutes any problem

We have noted rather conclusively that perfusion of the balloons with carbon dioxide will not in any way prevent the diffusion of the carbon dioxide through the wall of the balloon and into its lumen according to the law of diffusion of gases

An absolute prevention to the accumulation of the gas which permeates through the wall of the balloons of intestinal tubes consists merely in applying the tie to the balloon in such a fashion that the mercury remains trapped within the balloon but air can enter and leave In this case the slight pressure of the wall of

the bowel during peristaltic activity and the pressure of the liquid contents of the gastro-intestinal tract is sufficient to completely evacuate all gas from the balloons In addition, we are now in the process of changing all our latex balloons in the Cantor tube to neoprene-G This rubber, neoprene G is only nineteen per cent as permeable to carbon dioxide as is latex rubber By these two changes, we can completely prevent any accumulation of intestinal gases within the balloon of the Cantor tube

The law of diffusion of gases acting in a medium of a decompressed bowel is an adequate explanation for the rarity of finding gas in the balloons of intestinal decompression tubes clinically In our experience less than 0 3% of cases intubated demonstrate gas within the balloons. These cases are invariably ones in which the tubes are kept within a non decompressed paralytic bowel usually associated with infection within the peritoneal cavity or complete bowel atony This small incidence of occurrence can in our experience be completely eliminated in all types of mercury carrying intestinal decompression tubes

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CHAPTER XVIII

EFFECT OF HYDROGEN SULPHIDE GAS UPON THE BALLOONS OF INTESTINAL DECOMPRESSION TUBES

HYDROGEN sulphide gas is often found within the gastro-intestinal tract of patients with bowel obstruction This gas is not present in the air As has been noted the percentage of hydrogen sulphide gas found at times in the gastro-intestinal tract of patients with bowel obstruction has been reported variously from two to twelve percent. Because of this percentage of gas within the bowel which is far beyond the percentage that occurs in the balloons of intestinal tubes that contain a small amount of air it should be obvious that there would be a diffusion of the hydrogen sulphide from the bowel into the balloons until equal pressures for this gas is obtained

In his studies on the penetrativeness of gases Mitchell noted that rubber was highly permeable to hydrogen sulphide gas Following our studies with carbon dioxide gas, it therefore was imperative that similar studies be carried out with respect to hydrogen sulphide Because similar studies have never before been carried out and the medical literature contains no reports on this subject a complete report of these studies is being presented here.

Six experiments were carried out in our studies upon hydrogen sulphide gas The same apparatus was used that had been previously used in our studies upon carbon dioxide gas

EXPERIMENTS

A Experiment I

Five balloons were used in this experiment Hydrogen sulphide gas was passed into the pressure chamber containing the balloons which had been emptied of all air and then sealed The gas was passed into the chamber for forty eight hours The pressure of the hydrogen sulphide gas used in this experiment was thirty three mm of mercury for the first twenty four hours and

ten mm of mercury for the second twenty four hours In all experiments in which glass beads were used to keep the walls of the balloon apart, the volume of beads used was equal to the volume of mercury used in mercury containing balloons

Balloon 1 Harris tube latex balloon containing mercury
Balloon 2 Harris tube latex balloon containing beads
Balloon 3 Miller Abbott balloon containing mercury
Balloon 4 Cantor tube latex balloon containing mercury
Balloon 5 Cantor tube latex balloon containing beads

RESULTS OF EXPERIMENT I

At the end of forty eight hours, no gas was found in any of the balloons

Comment This unexpected result raised two questions First, was Mitchell correct? Is rubber highly permeable to hydrogen sulphide gas? Is it possible that no hydrogen sulphide could diffuse into the balloons? The second possibility was If rubber is permeable to the hydrogen sulphide gas, can it be so highly permeable that a rubber balloon cannot hold the hydrogen sulphide gas

With these possibilities in mind we proceeded to further experimentation in order to definitely decide these questions

B EXPERIMENT II

Four balloons were used in this experiment. Hydrogen sulphide gas was passed into the pressure chamber containing the balloons at a pressure of one hundred mm of mercury for twenty four hours The balloons were empty when placed into the pressure chamber and then sealed

Balloon 1 Harris tube latex balloon containing beads
Balloon 2 Cantor tube latex balloon containing beads
Balloon 3 Cantor tube latex balloon containing mercury
Balloon 4 Harris tube latex balloon containing mercury

RESULTS OF EXPERIMENT II

At the end of twenty four hours the following results were obtained

Balloon 1 Harris balloon with beads—this balloon took up 60 c.c. of hydrogen sulphide gas

Balloon 2 Cantor latex balloon with beads—this balloon took up 8 c c. of hydrogen sulphide gas

Balloon 3 Cantor latex balloon with mercury—no gas taken up Balloon discolored with a black deposit. Walls of the balloon were stuck together

Balloon 4 Harris balloon with mercury—no gas taken up Balloon discolored with a black deposit. Walls of the balloon stuck together

Comment This experiment is evidence for the fact that latex balloons are permeable to hydrogen sulphide gas In the presence of mercury, a mercuric sulphide forms and the walls of the balloon become discolored and adherent with the result that no cavity remains to hold the gas

Knowing now that latex balloons were permeable to hydrogen sulphide gas, we must determine the degree of permeability in order to explain the results of experiment I If latex balloons were highly permeable to hydrogen sulphide gas, then the explanation for the results in experiment I would be obvious

C. Experiment III

One balloon was used in this experiment whose purpose was the determination of the speed of outward diffusion of hydrogen sulphide gas from within the balloon of a Harris tube

Balloon 1 A Harris tube balloon was filled with hydrogen sulphide gas A pressure of five mm of mercury was sufficient to distend the balloon but not overstretch it We tried to avoid overstretching the balloon because that would not give a true outward gas diffusion reading

Results of Experiment III

At the end of *three minutes*, a definite loss of hydrogen sulphide gas was noted A definite wrinkling of the balloon appeared

At the end of *ten minutes*, the pressure of the hydrogen sulphide gas within the balloon had dropped to 3 mm of mercury The balloon was now half empty

At the end of *fifteen minutes* the pressure of the hydrogen sulphide gas within the balloon had dropped to 2 mm of mercury The balloon had now lost seventy five percent of its gas.

At the end of *twenty two minutes,* the balloon was almost completely empty There was less than ten percent of the gas remaining in the balloon

Comment Since the permeability of a rubber to a specific gas is the same under the same conditions regardless of whether the gas diffuses outward from within the balloon or from without into the balloon it becomes quite apparent that latex balloons are very highly permeable to hydrogen sulphide gas confined within them

D EXPERIMENT IV

Nine balloons were used in this experiment to determine the speed of diffusion of the hydrogen sulphide gas out of various kinds of balloons In all cases the balloons were inflated with the hydrogen sulphide just enough to distend them, but not to stretch their walls The balloons containing the gas were then sealed to prevent a loss of gas from their mouths Any loss of gas would then of necessity have to occur by diffusion through the walls of the balloons These balloons were then exposed to the air at room temperature. Since air contains no hydrogen sulphide, it was expected that an outward diffusion of the hydrogen sulphide gas from within the balloons would occur

Balloon 1 Balloon of Harris tube containing glass beads This balloon had previously been perfused with hydrogen sulphide for four days The rubber had lost its normal shiny translucent appearance and was not as elastic as when new The rubber was further affected by the hydrogen sulphide gas by having become milky white in appearance and opaque This balloon was filled with hydrogen sulphide gas until it was tense but not stretched This balloon was completely empty at the end of *twenty two minutes*

Balloon 2 Balloon of Harris tube containing mercury This balloon had previously been perfused with hydrogen sulphide for four days The balloon was discolored black and a definite black deposit was found within the balloon This balloon was filled with hydrogen sulphide gas until tense but not stretched This balloon was completely empty at the end of *twenty two minutes*

Balloon 3 Cantor latex balloon This balloon had previously

Balloon 2 Cantor latex balloon with beads—this balloon took up 8 c c of hydrogen sulphide gas

Balloon 3 Cantor latex balloon with mercury—no gas taken up Balloon discolored with a black deposit. Walls of the balloon were stuck together

Balloon 4 Harris balloon with mercury—no gas taken up Balloon discolored with a black deposit Walls of the balloon stuck together

Comment This experiment is evidence for the fact that latex balloons are permeable to hydrogen sulphide gas. In the presence of mercury a mercuric sulphide forms and the walls of the balloon become discolored and adherent with the result that no cavity remains to hold the gas.

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Balloon 2 Balloon of Harris tube containing mercury This balloon had previously been perfused with hydrogen sulphide for four days The balloon was discolored black and a definite black deposit was found within the balloon. This balloon was filled with hydrogen sulphide gas until tense but not stretched This balloon was completely empty at the end of *twenty two minutes*

Balloon 3 Cantor latex balloon This balloon had previously

been perfused with hydrogen sulphide gas for four days Hydrogen sulphide gas was then placed into the balloon until it was tense but not stretched At the end of *thirty minutes,* thirty per cent of the gas still remained within the balloon At the end of *ninety minutes,* there was still approximately thirty percent of the gas remaining in the balloon

Balloon 4 Cantor neoprene balloon containing glass beads. This balloon had previously been perfused with hydrogen sul phide gas for four days The balloon was filled with hydrogen sulphide gas until it was tense but not stretched At the end of *sixty minutes,* less than ten percent of the hydrogen sulphide gas had diffused out

Balloon 5 Cantor neoprene balloon which had never been used was now filled with hydrogen sulphide gas until it was tense. At the end of *sixty minutes,* less than ten percent of the gas had diffused out At the end of *two hours,* fifty percent of the hydrogen sulphide still remained within the balloon

Balloon 6 New latex balloon from Cantor tube This balloon was inflated with hydrogen sulphide gas until it was tense. *At the end of sixty minutes,* ten percent of the gas had diffused out At the end of *two hours* eighty percent of the gas had diffused out of the balloon There was less than one half of the amount of gas remaining in this balloon as compared with the neoprene balloon 5

Balloon 7 New Harris tube balloon filled with hydrogen sulphide until tense At the end of *twenty two minutes,* less than twenty five percent of the gas remained within the balloon. At the end of *twenty nine minutes* the balloon was almost completely empty At the end of *ninety minutes* the balloon was completely empty

Balloon 8 Balloon of Harris tube filled with air The balloon was tense At the end of *twenty five minutes,* there was no change in the balloon. At the end of *ninety minutes,* there was no change in the balloon

Balloon 9 Cantor neoprene balloon filled with air The balloon was tense At the end of *twenty five minutes* there was no change in the balloon At the end of *ninety minutes* there was no change in the balloon

Comment From this experiment it is readily evident that latex balloons are very highly permeable to hydrogen sulphide gas. Perfusion of the rubber balloons for four days prior to the test did not appear to change the degree of permeability of the balloons to any appreciable extent Neoprene balloons are seen to be far less permeable to the hydrogen sulphide than are the latex rubber balloons Mercury containing balloons of latex react with the hydrogen sulphide gas chemically forming mercuric sulphide This did not appear to change the degree of permeability of the balloon however Balloons filled with air retain the air for some time The outward diffusion of the nitrogen in the air is very slow Van Amerongen s studies indicate that oxygen occupies an intermediary position with regard to its permeability through rubber membranes

D Experiment IV A

Forty-eight hours after experiment four the balloons were again examined and the following observations made

Balloon 3 This balloon was found to be half full of air
Balloon 4 This balloon was found to contain one seventh of its capacity of air
Balloon 5 This balloon contained one tenth of its capacity of air
Balloon 6 This balloon contained one fifth of its capacity of air
Balloon 7 This balloon was empty
Balloon 8 This balloon showed very slight if any change
Balloon 9 This balloon showed very slight if any change

Comment Balloons 3 4 5 and 6 were previously thoroughly flushed out with hydrogen sulphide gas in order to expel all the air These balloons had been filled with hydrogen sulphide gas and sealed All the hydrogen sulphide gas was then diffused out of the balloons in three hours or less Although the balloons were still tightly sealed yet air had diffused into these balloons

F Experiment V

The purpose of this experiment was to determine whether a high pressure of hydrogen sulphide gas for twenty four hours would result in more gas diffusing into the collapsed empty bal

loons Four balloons were used in this experiment. We began with a pressure of 190 mm of mercury of hydrogen sulphide gas in the chamber This pressure dropped to 110 mm of mercury at the end of the experiment twenty four hours later

Balloon 1	Harris balloon with beads—this balloon took up 18 c.c. of hydrogen sulphide gas.
Balloon 2	Harris balloon with beads—this balloon took up 14 c.c of hydrogen sulphide gas
Balloon 3	Cantor latex balloon—this balloon took up 9 c.c. of gas
Balloon 4	Cantor neoprene balloon—this balloon took up 3 c.c. of hydrogen sulphide gas

Comment From this experiment, it is evident that using very high pressures of hydrogen sulphide gas does not appear to increase the diffusion of this gas into the empty balloons It is also evident that neoprene rubber balloons are far less permeable than the latex

F Experiment VI

Six balloons were used in this experiment. A pressure of sixty mm of mercury was maintained in the hydrogen sulphide gas chamber The balloons were empty and sealed when placed in the chamber The hydrogen sulphide gas pressure was maintained for twenty four hours

Results of Experiment VI

Balloon 1	Harris balloon—took up 100 c.c of hydrogen sulphide
Balloon 2	Harris balloon—took up 110 c c of hydrogen sulphide
Balloon 3	Cantor latex balloon—took up 20 c c of hydrogen sulphide
Balloon 4	Cantor latex balloon—took up 25 c c of hydrogen sulphide
Balloon 5	Cantor *neoprene* balloon—took up 8 c.c. of hydrogen sulphide
Balloon 6	Cantor neoprene balloon—took up 10 c.c of hydrogen sulphide

At the end of this experiment, after measuring the amounts of gas within the balloons, they were replaced within the pressure chamber and hydrogen sulphide gas was again passed into the pressure chamber. Twenty minutes later, when the gas chamber was opened, all the balloons were found to be empty.

Comment: This experiment clearly shows the very high degree of permeability of balloons to hydrogen sulphide gas. It is evident again that latex is far more permeable than neoprene to this gas.

SUMMARY OF THESE EXPERIMENTS AND CONCLUSIONS

These experiments clearly show that latex intestinal tube balloons are far more permeable to hydrogen sulphide gas than are neoprene balloons. The hydrogen sulphide gas appears to change the character of the rubber balloons. There is a loss of elasticity and a marked discoloration of the rubber. If mercury is present in the balloons, a mercuric sulphide is formed as a black deposit within the balloon. This does not change the degree of permeability of the balloons. Perfusion of the balloons with hydrogen sulphide gas does not appear to change the permeability of the rubber.

Because the balloons of intestinal tubes are so highly permeable to the hydrogen sulphide gas, this specific gas does not constitute a hazard in intubation even when found in appreciable amounts in the gastro-intestinal tract. The reason for this is the fact that with intestinal decompression and the removal of intestinal gas (hydrogen sulphide) that the gas within the balloons rapidly diffuses out of the balloons in a matter of minutes.

We observed in experiment IV A that after the hydrogen sulphide diffuses out, over a period of many days that air may diffuse in. This unusual occurrence can readily be prevented by the safety valve in the Cantor tube and the caliber of the tube which avoids occlusion of the lumen.

DOES THE BOWEL PREVENT THE OUTWARD DIFFUSION OF GAS FROM WITHIN THE BALLOON OF INTESTINAL DECOMPRESSION TUBES?

We have already shown beyond any reasonable question of doubt that balloons of intestinal decompression tubes are permeable to intestinal gases Although we have developed a method of tying on the balloon of intestinal tubes so as to prevent the accumulation of gas within the balloons, yet cases are being reported in which a considerable distention of the balloons occurs because of an error in applying the tie or the development of a knot in the Miller Abbott tube Several fatalities have been reported to the author because the surgeon failed to realize the significance of an increase in gas within the intestinal tube balloons or did not know how to contend with this complication

In our studies upon the permeability of intestinal balloons to carbon dioxide gas and hydrogen sulphide gas, we were able to show in vitro that if the bowel circumjacent to the balloons is decompressed the gas within the balloons would diffuse out. The diffusion outward of the hydrogen sulphide is very rapid occurring in a matter of minutes Carbon dioxide, although it diffuses out much slower nevertheless will completely diffuse out of the balloons exposed to the air in less than twenty four hours. Since these studies were carried out in vitro by exposing the balloons to atmospheric air and since only carbon dioxide and hydrogen sulphide were used the question arose as to whether the same findings would hold true for balloons within the intestinal tract and for balloons filled with air

The great importance of such studies is quite apparent in that we would then be in a position to tell the surgeon with a definite degree of certainty just what to expect when roentgenograms disclosed a balloon distended with gas Very often the first indication that the surgeon has that something unusual has occurred is the cessation of suction decompression in the case of the Miller Abbott tube or the inability on the part of the surgeon to remove the intestinal tube

This experimental study was divided up into four parts, and

an effort made to reproduce in vivo conditions as closely as possible.

A. Experiment I

This experiment had as its purpose to demonstrate the effect of fluid in contact with the balloons of intestinal tubes upon the permeability of the balloons to various gases Twelve balloons were used in this study The volume of gas in the balloon was measured by the water displacement method

Air filled balloons

(a) Cantor balloon (latex) inflated with air	22 c c
(b) Cantor balloon (neoprene) inflated with air	35 c c
(c) Harris balloon inflated with air	117 c c.
(d) Miller Abbott balloon inflated with air	61 c c

Carbon dioxide filled balloons

(a) Cantor balloon (latex) inflated with carbon dioxide	33 c c.
(b) Cantor balloon (neoprene) inflated with carbon dioxide	64 c c
(c) Harris balloon inflated with carbon dioxide	254 c c
(d) Miller Abbott balloon inflated with carbon dioxide	90 c c

Hydrogen sulphide filled balloons

(a) Cantor balloon (latex) inflated with hydrogen sulphide	17 c c
(b) Cantor balloon (neoprene) inflated with hydrogen sulphide	47 c c
(c) Harris balloon inflated with hydrogen sulphide	182 c c
(d) Miller Abbott balloon inflated with hydrogen sulphide	64 c c

These balloons were then submerged in shallow pans containing water The balloons were completely covered by the water Seven thousand c c of water was used in each pan. The temperature of the water was 13 degrees centigrade Three pans were used. One pan for each group of four balloons At the

end of three hours all the balloons were examined, and then at the end of twenty four hours all the balloons were re-examined.

RESULTS OF EXPERIMENT I

At the End of Three Hours

A Air filled balloons

(a) Cantor balloon (latex)	22 c.c.
(b) Cantor balloon (neoprene)	35 c.c.
(c) Harris balloon	117 c.c.
(d) Miller Abbott balloon	61 c.c.

A comparison of these values with those at the beginning of the experiment shows there to be no loss of air from any of the balloons at the end of the three hour period

B Carbon dioxide filled balloons

(a) Cantor balloon (latex)	3 c.c.
(b) Cantor balloon (neoprene)	53 c.c.
(c) Harris balloon	24 c.c.
(d) Miller Abbott balloon	6 c.c.

A comparison of these values with those at the beginning of the experiment shows that there has been a considerable loss of carbon dioxide from all the latex balloons but only a small loss from the neoprene balloon The actual loss of carbon dioxide gas from each balloon was as follows Cantor balloon (latex) showed a loss of 30 c.c. or 90% of its gas Cantor neoprene balloon showed a loss of 11 c.c. or 17% of its gas Harris balloon showed a loss of 230 c.c or 90% of its gas Miller Abbott balloon showed a loss of 84 c.c. or 93% of its gas

C Hydrogen sulphide filled balloons

(a) Cantor balloon (latex)	3 c.c.
(b) Cantor balloon (neoprene)	28 c.c.
(c) Harris balloon	8 c.c.
(d) Miller Abbott balloon	8 c.c.

A comparison of these values with those at the beginning of the experiment shows that there has been a marked loss of hydrogen sulphide gas from all the latex balloons but again only a small

loss from the neoprene balloon The actual loss of hydrogen sulphide gas from each balloon is as follows Cantor (latex) balloon showed a loss of 14 c c or 82% of its gas The Cantor (neoprene) balloon showed a loss of 19 c c or 40% of its gas The Harris balloon showed a loss of 174 c.c. or 95% of its gas The Miller Abbott tube balloon showed a loss of 56 c c or 87% of its gas

At the End of Twenty-four Hours

At the end of twenty four hours, these balloons were re examined It was now found that all the balloons filled with air had lost little if any gas The balloons filled with carbon dioxide and hydrogen sulphide gas were found to be completely empty

These results when compared with our previous studies upon the diffusion of gases from within the balloons when exposed to air shows essentially the same speed of loss of the various gases It is thus evident that the submersion of the balloons in water did not in any way change the speed of diffusion of the various gases It must also be noted that within the twenty four hour period that there was no diffusion of the air filled balloons through the walls of the balloon This observation is important in the light of the many observations that air can be found within the balloons of the intestinal tubes The presence of a safety valve by tying the balloons over a 22 Fr stylet would effectively prevent this occurrence since the air would readily escape through the vent that was left when the stylet was removed after the application of the tie was complete

B Experiment II

This experiment had as its purpose to show the effect of the close approximation of the human bowel wall upon the gas trapped within various intestinal tube balloons In this experiment, balloons of intestinal tubes were inflated with various gases and then the balloons were sealed to prevent the escape of the gases The gas inflated balloons were then inserted into sections of human small intestine taken from an hour old autopsy Three sections of human bowel were used Each group of balloons containing the same gas were inserted into a different section of

bowel The distended balloons when inserted into the bowel caused a marked distention of the bowel and a very close approximation of the bowel to the wall of the balloon. The ends of the bowel were then tied off Each section of bowel was then immersed in a pan or normal saline at 13 degrees centigrade Seven thousand c c of saline were used in each pan Three pans were used—one pan for each section of bowel

Air filled balloons

(a) Cantor (neoprene) balloon	36 c.c.
(b) Cantor (latex) balloon	23 c.c.
(c) Harris balloon	119 c.c.
(d) Miller Abbott balloon	64 c.c.

Carbon dioxide filled balloons

(a) Cantor (neoprene) balloon	26 c.c.
(b) Harris balloon	125 c.c.
(c) Miller Abbott balloon	53 c.c.

Hydrogen sulphide filled balloons

(a) Cantor (neoprene) balloon	27 c.c.
(b) Harris balloon	76 c.c.
(c) Miller Abbott balloon	41 c.c.

At the End of Three Hours

A Air filled balloons

(a) Cantor (neoprene) balloon	no loss or air
(b) Cantor (latex) balloon	no loss of air
(c) *Harris balloon*	no loss of air
(d) Miller Abbott balloon	no loss of air

B Carbon dioxide filled balloons

(a) Cantor (neoprene) balloon	25% loss of gas
(b) Harris balloon	75% loss of gas
(c) Miller Abbott balloon	75% loss of gas

C Hydrogen sulphide filled balloons

(c) Cantor (neoprene) balloon	50% loss of gas
(b) Harris balloon	75% plus loss of
(c) Miller Abbott balloon	75% plus loss of

At the End of Twenty-four Hours

At the end of twenty four hours the air filled balloons shown no significant loss of air The carbon dioxide anc hydrogen sulphide filled balloons had lost all their gas and now found to be empty

C. Experiment III

This experiment had as its purpose to show the effect o close approximation of the human bowel containing inte contents, taken from a case of bowel obstruction, upon the ward diffusion of gases trapped within the balloons of inte tubes In this experiment, balloons of intestinal tubes wer flated with various gases and then the balloons were seal prevent the escape of the gases The gas inflated balloons then inserted into sections of human small intestine taken an hour old autopsy Three sections of human bowel were Each group of balloons containing the same gas were insert a different section of bowel The distended balloons whe serted into the bowel caused a marked distention of the bowe a very close approximation of the bowel to the wall of the bal The bowel was then filled with intestinal secretions taken a case of bowel obstruction The ends of the bowel were tied off Since we had amply demonstrated that the out diffusion of air was negligible in the twenty four hour perio decided to omit the air filled balloons in this experiment. We only Harris balloons and Cantor neoprene The behavior c Harris balloon and that of the Miller Abbott balloon wa same Because latex Cantor balloons are no longer being r factured, but neoprene used instead as a result of our studie decided to use neoprene only

Carbon dioxide filled balloons

(a) Harris balloon filled with carbon dioxide	90 c.c.
(b) Cantor (neoprene) balloon filled with carbon dioxide	26 c.c.

Hydrogen sulphide filled balloons

(a) Harris balloon filled with hydrogen sulphide	92 c.c.
(b) Cantor neoprene balloon filled with hydrogen sulphide	33 c.c.

At the End of Four Hours

A Carbon dioxide filled balloons

(a) Harris balloon	50% loss of gas
(b) Cantor (neoprene) balloon	10% loss of gas

B Hydrogen sulphide filled balloons

(a) Harris balloon	75% loss of gas
(b) Cantor (neoprene) balloon	25% loss of gas

At the End of Twenty-four Hours

All the balloons containing carbon dioxide and hydrogen sulphide were found to be empty

D Experiment IV

The purpose of this experiment was to determine whether intestinal secretions alone could cause gas to diffuse into balloons of intestinal tubes. For this experiment four hundred c.c. of intestinal contents removed from a case of bowel obstruction was used. Two intestinal tube balloons containing mercury were submerged in this juice for twenty four hours and then examined for gas.

At the End of Twenty-four Hours

An examination of the balloons at the end of four hours had *shown no gas within the balloons* The balloons were then re examined at the end of twenty four hours and were found to be empty No gas had diffused into either balloon.

Summary of These Experiments and Conclusions

The speed of outward diffusion of hydrogen sulphide and carbon dioxide gas from within the balloons of intestinal decompression tubes is uninfluenced by the media in which they occur Exposure to air, submersion in water, insertion within the empty bowel or insertion within a bowel filled with intestinal secretions does not result in any change in the speed of outward diffusion of the various gases Hydrogen sulphide gas is the most rapidly diffusible from the balloons Neoprene balloons are far less permeable under all conditions than are latex balloons

This study shows clearly that, if an intestinal decompression balloon becomes inflated with carbon dioxide or hydrogen sulphide that the passage of a second intestinal tube to decompress the circumjacent bowel would rapidly result in the diffusion of the hydrogen sulphide and the carbon dioxide from within the balloon into the bowel The speed of diffusion of the hydrogen sulphide is so fast that it is extremely doubtful whether this gas enters into the problem at all The only possible influence this gas might have is suggested by our observations that balloons filled with hydrogen sulphide rapidly lost this gas in less than two hours If then these balloons were permitted to lie exposed to air, they might take up some of the air This diffusion of air into balloons formerly filled with hydrogen sulphide might then constitute a real problem in intubation The reason for this is obvious from our observations that the air filled balloons showed very little loss of air in twenty four hours When we recall that approximately eighty percent of the air consists of *nitrogen* a gas which is extremely slowly diffusible through a rubber membrane, it becomes obvious why this should be so Once air has accumulated within the intestinal tube balloon then many days of bowel decompression is required before the air diffuses out. The best treatment for this condition is to prevent it by the use of the safety valve vent as described earlier in this text Fortunately, this sequence of events is uncommon, occurring in less than one half percent of all cases

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